July, 1940

Heating · Piping and Air Conditioning

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INDUSTRY buildings air conditioning for effi- and safety, says Walter eisher in an editorial on 31 (front section)

KERS LIFE new home building is air conditioned, nique wall warming sys- complete control installa- See page 405

L ENGINEERING is d for success in air condi- ng hotel guest rooms. en D. Lewis tells why, page

WATER heating plant for ge apartment development G. Wohlfarth's subject on 413. The pumps are illu- d here

Page 437

Journal Section
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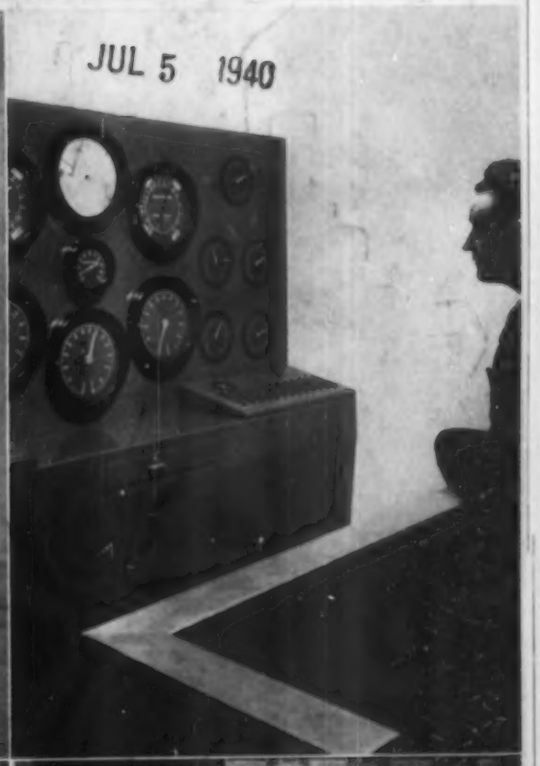

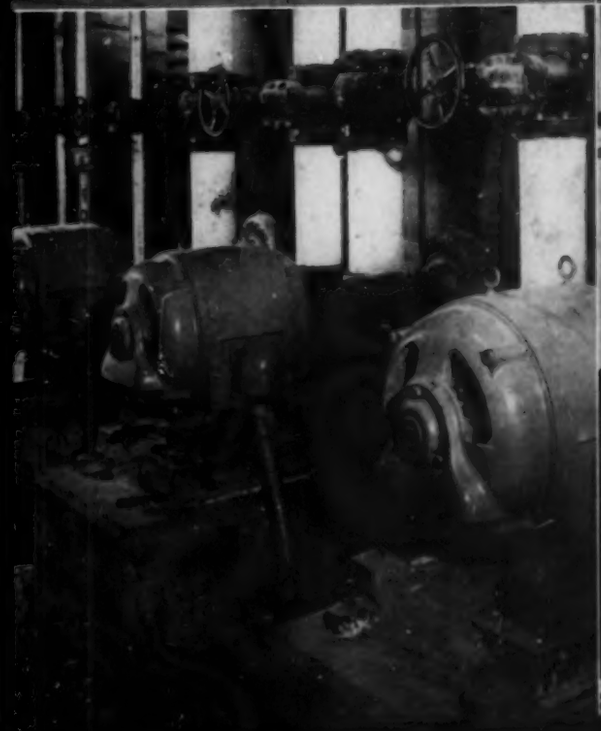

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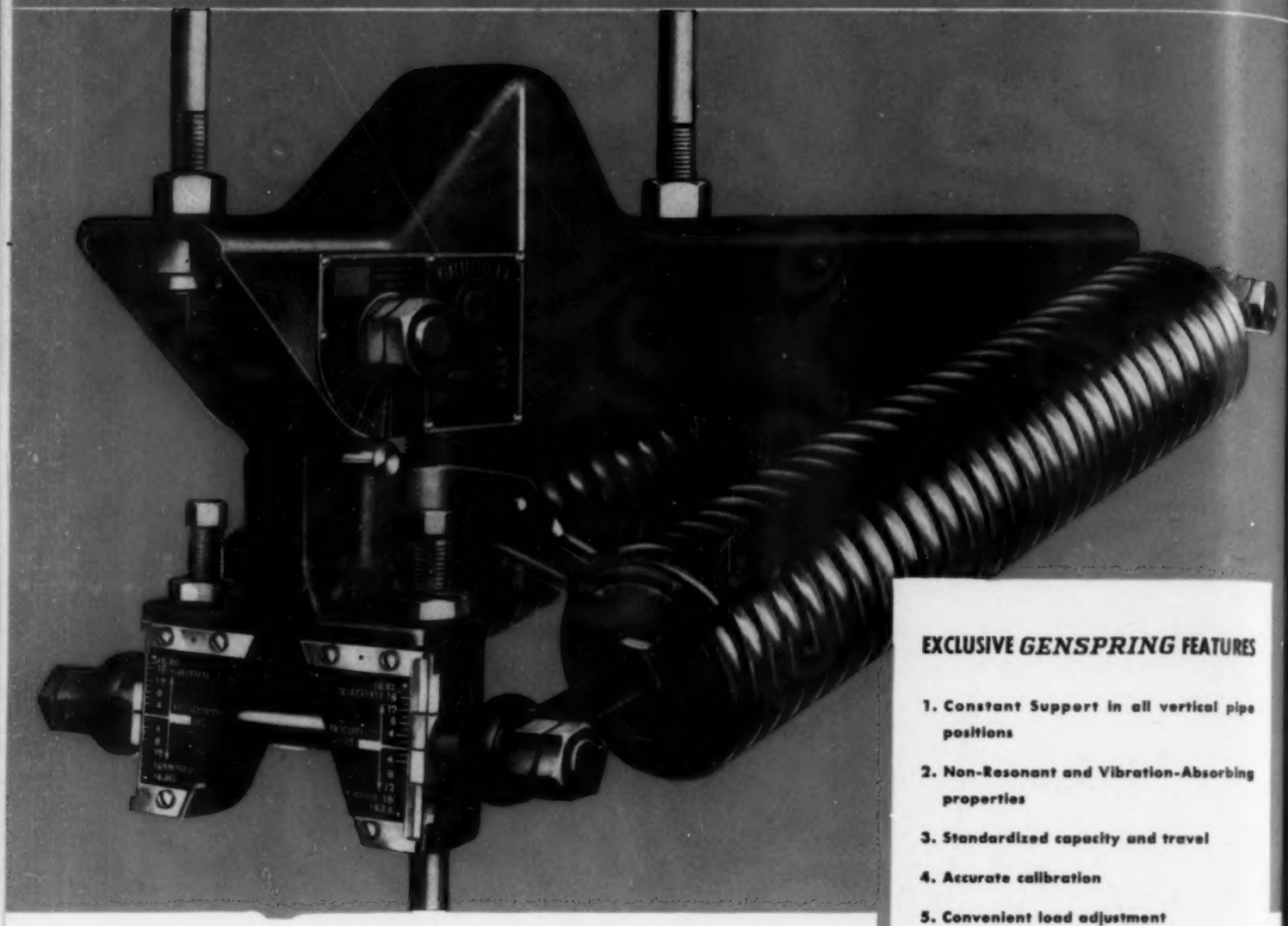

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CONTENTS *for* JULY, 1940

Volume 12 — Number 7

Air Conditioning for War—an editorial by Walter L. Fleisher (front section) 31

Wall Warming System Complements Air Conditioning of New Building.. 405

Will These Piping Changes Pay?, by A. C. Kirkwood..... 410

Air Conditioning Attracts Tourists, by P. J. Rinderle..... 412

The Design and Installation of a Central Hot Water Heating Plant, by C. G. Wohlfarth..... 413

Hotel Guest Room Air Conditioning Requires Good Engineering Design, by Warren D. Lewis..... 417

Air Conditioning an Essential in Many Industrial Processes..... 420

Radiant Heating and Cooling, by F. E. Giesecke..... 421

Important Task for Air Conditioning, Shepard Tells ASRE..... 424

The Use of the Ring Joint on Oil and Steam Piping Service, by F. R. Venton and A. W. Marburg..... 425

Water Treatment for Heating Boilers, by Kalman Steiner and Ralph A. Nelson 428

The Psychrometric Chart—Its Theory and Application, by William Goodman 431

Contractors Hear Air Conditioning, Heating Committee Reports..... 433

Keep the Piping Clean—A "Must" at Pinkham Medicine Co., by Otis E. Russell (with Francis A. Westbrook)..... 434

Properties of Mixtures of Air and Saturated Water Vapor for Barometric Pressures from 22 In. to 32 In. of Mercury, by William Goodman.... 435

Electric Heat Maintains Free Flow of Asphalt, by J. Schneider..... 436

Equipment Developments (back section)..... 104

Book Reviews (back section)..... 114

Booklets, Reports and Papers (back section)..... 115

Conventions and Expositions (back section)..... 119

Recent Trade Literature (back section)..... 120

Index to Advertisers (back section)..... 128

[Front cover photos—Upper left, U. S. Navy Recruiting Bureau; upper right, Hedrich-Blessing Studio; lower left, Norman L. Cook; lower right, Morris Landau.]

Journal Section of the American Society of Heating and Ventilating Engineers

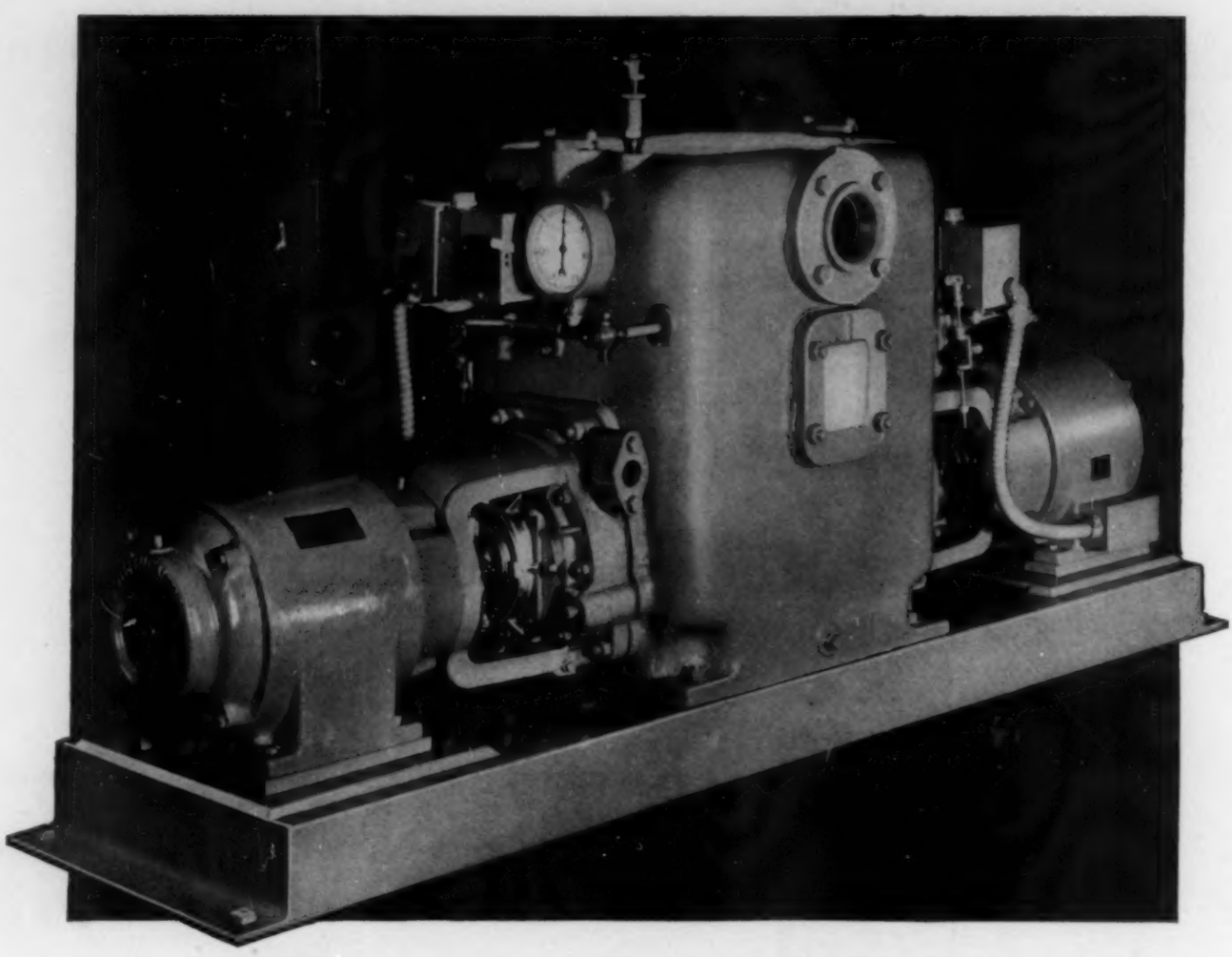
Effect of Room Dimensions on the Performance of Direct Radiators and Convectors, by A. P. Kratz, M. K. Fahnestock, E. L. Broderick and S. Sachs 439

Methods of Rating the Noise from Air Conditioning Equipment, by J. S. Parkinson 447

Summer Cooling Load as Affected by Heat Gain Through Dry, Sprinkled and Water Covered Roofs, by F. C. Houghten, H. T. Olson and Carl Gutberlet 451

Transverse Heat Conductivity of Wood, by Frederick F. Wangaard..... 459

Bulletin Section 464



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THE EDITOR'S PAGES

Air Conditioning for War

An Editorial by Walter L. Fleisher*

TWENTY-FOUR hours a day—six or seven days a week—may be the rôle of industry before the menace of Europe is past. The wear and tear on the worker, the nerve strain coincidental with the physical labor, is not only likely to impair the health of the worker but his efficiency as well. To allay this unfortunate condition, to make it possible to produce more goods and goods of better quality, air conditioning can do much. With efficient lighting, high powered, fast moving machines, congestion of people, one story buildings with intense sun effect on the roofs, temperatures may rise to 100 F or more and the relative humidities to 60 or 70 per cent. Here, if men put out sufficient effort to produce goods, their high metabolism will definitely result in a rise in body temperature, increased pulse rate, sweating and discomfort, which cannot help but reduce their output and, possibly, destroy their coördination. The fumes of cutting oils, the gases of engines, the sweat, will all tend to a deterioration of product that the very necessity of increased production cannot afford. Many of our new industrial plants, built in a hurry, are neglecting the opportunity of overcoming these conditions and are installing only the simplest methods of heating to overcome differences of temperature in the wintertime. Open windows and skylights are being made to serve the purpose of ventilation in the summer or during hot weather.

What was adequate in the past will not serve the future. Now is the time to prepare for an emergency.

If war should come to America, then the objective of attack would be our industrial plants turning out emergency material. These plants, working day and night, if lighted like a burning torch would be the finest targets for night attacks of planes. They would have to black out in order to avoid attack. Closed doors and windows—or, better still, no windows—or buried or half-buried structures are the alternative. What ventilation there was would have to be artificial. The industrial air conditioning engineer is prepared for this contingency, because some plants in this country have already been built that way, and air conditioning has more than adequately taken care of the necessary heating, cooling and ventilation. Let us see what this may mean in equipment and expense, and how the equipment can be safeguarded against breakdown; and what the minimum requirements for health and comfort are.

We can say, from research already completed, that conditions over 78 F effective temperature are too high. This means conditions over 85 F and 53 per cent relative humidity, and a dew point of 65 F, requiring either refrigeration, well water around 54 F or dehydration by means of absorbers or adsorbers, plus cooling tower or city water. Plants could be situated in dry, low wet bulb locations, where these conditions could be obtained by evaporative cooling without the use of refrigeration. It would be well at this time to examine these locations carefully with that idea in mind.

The average large plant might have a floor area of 80,000 to 180,000 sq ft and require 500 to 1000 tons of refrigeration effect to produce satisfactory results when working at full production, with lights, people and machines going at full tilt. Each ton of refrigeration effect means that from 400 to 500 cfm of air would have to be circulated and not less than 15 or 20 per cent would have to come from out-of-doors for dilution and to overcome outward leakage. The cost of such a system, with refrigeration, will run from a minimum of $200 to $300 per ton, and, if based on the square foot of floor space, from $1.00 to $1.50 per sq ft. This may seem a high figure, but it must be remembered that the concentration of power, lights and people is usually great in these new industrial plants.

If we make our workers dependent on artificial conditions, which in most instances will be better than so-called natural conditions, and if we make it impossible for them to obtain ventilation unless these systems are working, we must see that precautions are taken to prevent the system from becoming inoperative.

Chimneys can be destroyed, power stations interrupted, water supplies broken. Therefore, the systems should be able to run without dependence on these things. Diesel power, with submerged oil tanks, for operating fans and refrigeration; well water or storage and inside cooling towers or evaporative washers; dehydrators for lowering the dew point of the air and filtering out obnoxious fumes; all make possible the operation of the systems without interruption and make possible the output of needed goods in times of emergency without danger to the worker or deterioration of the product.

This is the story in its briefest form. This is an emergency editorial. It is written simply to awaken American industry to conditions that I found existent in Europe; conditions which were inadequately taken care of until the emergency had already occurred and it was too late to profit from advice. The best and most adequate plant in the world is of no value after it has been destroyed. When I returned from Europe, both last year and the year before, I warned everyone with whom I came in contact that many of the things which have since taken place were likely to occur. We can do many things now, with our knowledge of what has happened and what may happen, that it may be too late to accomplish if we hesitate and delay. I believe that the unwillingness to spend money was as much responsible for what has happened as any single factor. I would advise that money should not be the factor to jeopardize our own preparedness program.

*Consulting and Advisory Engineer. Member of HPAC's Board of Consulting and Contributing Editors.

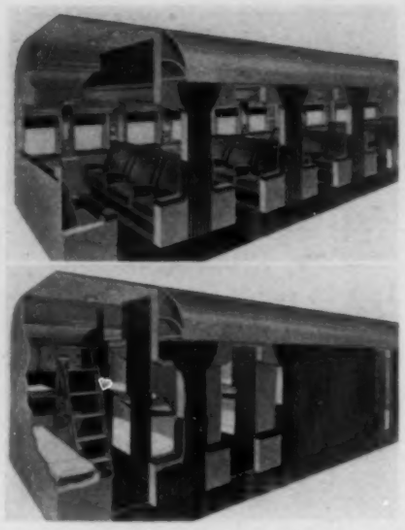
CARRIER CRITICIZES TECHNICAL EDUCATION

Dr. Willis H. Carrier discussed needed improvements in our system of technical education at the semi-annual meeting of the American Society of Mechanical Engineers last month. His suggestions were based on his experience as an employer of engineering graduates.

At least five different features in our present day technical education are justly subject to criticism, he said, and although they do not apply equally to all institutions, they can be accepted as fair criticism of the average institution. These are the trend toward specialization in undergraduate courses, lack of proper standards for selection of students to be admitted to engineering courses, failure to develop in the student the habit of thorough understanding of subject matter and processes, insufficient emphasis placed on development of student personality, and examinations and student grading which are not the true test of student ability desired by the employer.

It would seem that there is one underlying error common, at least in practice if not in theory, in most of our institutions to which these various faults may be traced, Dr. Carrier said. This is the failure to appreciate that the chief objective of a technical education should be to train the student in logical thinking and develop his creative imagination; that it should be aimed primarily toward the acquisition of power rather than toward the amassing of factual knowledge. Many educators will not admit that this is a sound accusation, he said, but he insisted that while many agree with this statement in theory, they fail to carry it out effectively in practice.

What the employer wants is to be able to select college graduates with greater surety of their success in his particular field because of their *proved* natural ability and because of their sound grounding in engineering fundamentals, he concluded.



The Pullman Co. has developed and is building a new type of railway car, a coach-sleeper. During the daytime, passengers occupy upholstered adjustable seats which at night are made up into berths which have individual curtains; there are also aisle curtains which are drawn across the compartment entrances during dressing periods. These new cars are designed to appeal to rail travelers who want sleeping service at minimum cost for both transportation and the reserved accommodation. The air conditioning for these cars is of the standard Pullman mechanical type. There is a main air inlet over each compartment door and a supplementary air inlet at the head of each berth, the latter for night use manually controlled by the passenger

HANLEY NOMINATED FOR ASME PRESIDENCY

William A. Hanley, in charge of engineering, Eli Lilly & Co., and a member of HPAC's board of consulting and contributing editors, has been named by the national nominating committee of the American Society of Mechanical Engineers as nominee for the office of president. The chairman of the committee, Prof. O. A. Leutweiler, announced the nominees at the semi-annual meeting of the ASME in Milwaukee last month.

AIR CONDITIONED CHEESE MINES

An interesting recent development is the utilization of abandoned coal mines in Pennsylvania for curing Roquefort type cheese, according to the Industrial Bulletin of Arthur D. Little, Inc. Through a systematic investigation, an enterprising cheese manufacturer discovered that one mine had an abandoned drift in which conditions were ideal. The humidity was maintained at nearly 100 per cent by air passing through a drift at a lower level which was partly filled with cold water. The temperature varied only slightly from 46 to 48 F throughout the year, and by constructing a few dampers to control the movement of air an excellent aging room was made available.

According to the Industrial Bulletin, although artificial curing chambers are widely used in Denmark, American efforts have been directed toward finding natural caves, which have the advantage of low operating cost. This is an important factor, since mold type cheeses require longer curing periods than bacterial types.

BERGDOLL APPOINTED CHIEF ENGINEER

Llewellyn Williams, vice-president in charge of engineering of the York Ice Machinery Corp., has announced the appointment of John G. Bergdoll as chief engineer of the corporation. Mr. Bergdoll, born in Philadelphia in 1898, was first employed by York as a machinist's apprentice in 1914 in connection with the corporation's high school coöperative course, and since then has occupied the positions of draftsman, equipment development engineer, product engineer, and assistant chief engineer.

D. W. RUSSELL NAMED AIRTEMP PRESIDENT

K. T. Keller, president of Chrysler Corp., has announced that D. W. Russell has been selected president of Airtemp, the company's air conditioning and heating division. Mr. Russell came to Chrysler in 1931. He has done technical and sales work in the company's Fargo division, of which he was made a vice-president in 1932.

ELECTED TO FRICK BOARD

W. H. Aubrey, vice-president of the Frick Co. and sales manager of the ice and refrigerating machinery department, was recently elected to the board of directors. Mr. Aubrey, a graduate of Georgia Tech, has been with Frick nearly 23 years and has been sales manager since 1932.

GETTING READY FOR MASS PRODUCTION DEFENSE PROGRAM TAKES TIME, SAYS KETTERING

Charles F. Kettering, vice-president of General Motors in charge of research, last month pointed out to the American people that failure to understand the real meaning of mass production in relation to the country's defense preparations might lead to "a disappointment." Mr. Kettering spoke at a luncheon at the New York World's Fair given to mark the formal opening of the new "previews of progress" science stage show in the auditorium of the highways and horizons building.

Discussing the nation's defense program, Mr. Kettering said that reports of producing 1000 planes a day might tend to create a false impression in people's minds, because the average American doesn't realize how long it takes to get ready to produce machines on a mass production basis.

American industry, he said, stood ready to produce large quantities of defense equipment, but it was up to the military authorities to decide first what type of equipment was needed. He said it was not a question of producing things "we would like to have" but rather of deciding what things it would be easiest to produce in greatest quantity.

Heating·Piping and Air Conditioning

Vol. 12, No. 7 • July, 1940

The Bankers Life building superintendent looks over his control board. Selector switches on the panel at the lower left enable him to get readings on the electrical thermometer (directly beneath the clock) of temperatures at key points in the apparatus and at 24 stations throughout the building. A six point recorder immediately above this panel charts the trend of various conditions affecting operation. The panel at the lower right contains a master thermostat and pilot lights for the various items of equipment — fans, spray pumps, compressors, radiant heaters, booster heaters, boilers and air cleaner. The center of the board contains a combustion recorder and dials indicating header steam pressure and the fuel supply, and flow meters for water

Wall Warming System Complements Air Conditioning of New Building

Bankers Life Builds Home Office Building With Noteworthy Features — Air Conditioning an Integral Part of Design

A UNIQUE wall warming system that works as a complement to the air conditioning and is designed to make every square foot of floor space comfortable and usable—right to the exterior walls—is a feature of the new home office building of the Bankers Life Co., Des Moines, Iowa. Called by a leading architectural magazine "the building of the decade," the structure is noteworthy in many respects.

Tinsley, McBroom & Higgins were the architects and the consulting engineer was Charles S. Leopold.

The wall warming scheme used should not be confused with "radiant heating," although in some respects its objectives are the same. Radiant heating is generally used to describe a type of heating system in which the ceilings, floors or walls are heated to a degree that will permit comfort of the occupants at a general room temperature substantially below present accepted standards. In systems of this type the heating pipes are usually embedded in the building material and the building surface raised to temperatures in excess of 100 F. In the Bankers Life building it is necessary to heat the wall only to a temperature at which the average radiating temperature of the windows and outside walls will limit the rate at which the body loses heat by radiation, and to approximate the average radiating temperature of interior walls, floor and ceiling; the required tempera-

The new $2,000,000 home office building of the Bankers Life Co., Des Moines, Iowa, offered a number of interesting air conditioning and heating problems, and the solutions were equally noteworthy. As this photo shows, the building consists of six principal floors, a ground floor, and a partial seventh floor. There is also another basement below the ground floor. Windows throughout are double glazed, and with the exception of those on the sixth floor, are set in panels of glass block. The cooling tower was constructed as a part of the structure with only the inlet louvers visible from the outside. The building has many features

The electrostatic air cleaner installation. Especially effective in removing smoke particles, this device gives to all foreign matter carried in by the air from outside a positive electrical charge. Small platinum wires running lengthwise along both sides of each unit carry a 13,000 volt charge for this purpose. Then the air passes between two metal plates, one charged positively with 6000 volts and the other negatively charged and grounded. As the air passes through the electrostatic field thus set up, the positively charged dirt particles are repelled by the positive and attracted by the negative plate. Trapped on this plate, they are permanently removed from the air supply and the 550 Bankers Life employees can do their work more healthfully and efficiently as a result. Spun glass filters in the recirculated air assist in removal of dirt

ture is thus in the vicinity of 70 F. With this installation, local sensations of warmth or coolness from interior partition to outside wall are practically eliminated.

In this connection, the wall construction of the building plays an important role. In the clerical areas on the five principal floors, factory-enameled steel panels are used. Behind these wall panels the entire building is insulated by a 2 in. layer of cork. Between the cork insulation and the sectional steel panels, a system of 1 in. bare copper tubes loops around and under the window openings. In winter hot water will be pumped through the tubes to balance heat loss through the double windows and the cork insulation.

Although the air conditioning system is capable of heating the structure, in a cold climate such as Des Moines it is usually desirable to provide separate means of heat adjacent to the window and wall areas in order to counteract the cold sensation due partly to the descending current of relatively cool air directly adjacent to the wall or glass surface, and partly to the sensation of cold caused by the body radiating heat directly to the cold surface. In the design of this building, unusual effort was made to make the working spaces completely usable, as reflected (for instance) by the elimination of columns. This same thought was extended in the selection of the perimeter warming system and it was desired to eliminate concentrated sources of heat directly adjacent to the windows as well as the grilles and openings which would be required for convection radiators. The fact that it had been determined to insulate the outside walls and that there would be a space between the inside and outside walls (whether the interior wall was to be of plaster or metal) aided in the solution of the problem from the standpoint of cost in that no additional construction was required and heat loss from the relatively warm space to the outdoors was greatly reduced.

Use of this space around the perimeter of the building adds 8 per cent to the total useful floor area. The elimination of columns permits a further increase of more than 12 per cent. Consequently the architect in charge, Leland A. McBroom, estimates that the company would otherwise have had to add another entire floor to the building in order to furnish equivalent working space. This is one of the savings achieved in the building by taking the long-run point of view.

With the wall and window heat losses supplied in this manner, the air delivered by the conditioning system will vary from room temperature downward, even in the winter. The wall warming system will also be used during the winter when the building is not occupied and will serve to keep the building at the proper temperature so that the minimum time will be required to reach proper conditions in the morning. The wall warming system was essentially designed for winter service but has been equipped so that chilled water can be circulated in hot weather.

Check of wall and window temperatures was made by thermocouple at a time when the air conditioning system was not in operation. The widest difference in temperature of the wall from floor to ceiling was three degrees, the highest temperature occurring directly beneath the window.

In the left foreground several of the sectional steel wall panels have been removed to show the 1 in. bare copper piping of the unique wall warming system. This piping carries hot water under forced circulation, balances any thermal losses through the windows and the 2 in. layer of cork insulation which lines the exterior masonry walls throughout the building. Unlike radiant heating as it is generally known, the Bankers Life wall warming system maintains wall and window temperatures of 70 F

Double glass windows are used throughout the building. With the exception of the sixth floor, all windows are set in panels of glass brick. This frame of glass blocks is shaded so far as possible by projecting piers, so that radiant heat stored in the blocks will be reduced. At the north side of the building glass brick is used to a greater extent, since the problem of sunlight and radiant heat is eliminated there.

Air Conditioning an Integral Part

In the design of the building, the air conditioning was incorporated as an integral part of the structure and the architect therefore could take advantage of it in the building design. Window and glass areas were selected to meet the need for daylight without having to consider natural ventilation. The air conditioning system thus is vital to successful operation of the building in all seasons.

SUMMARY

A unique wall warming system, comprising copper piping through which hot water is circulated, is one of the numerous features of the new home office building of the Bankers Life Co. at Des Moines, Iowa. Not to be confused with "radiant heating," object of the wall warming is to maintain exterior wall and window surfaces at about the same temperature as interior wall, floor and ceiling surfaces, thus make the entire floor area right up to the exterior walls usable. The architect estimates that use of this space around the perimeter adds 8 per cent to the useful floor area. Elimination of columns permits a further increase of 12 per cent. Thus, the company would otherwise have had to add another entire floor in order to furnish equivalent working space. . . . . Total capacity of the refrigeration plant for summer air conditioning is 650 tons. The air conditioning is completely zoned, and there is an elaborate control system to promote economical and satisfactory operation. . . . . The heating and air conditioning of this structure, which has been called "the building of the decade" by a leading architectural magazine, is described in some detail here

Two main conditioned air fans and the fan used for return and exhaust are situated in the pent house adjacent to the elevator equipment. The duct distribution of conditioned and return air is substantially vertical through the utility shafts of the building. In the gen-

This is part of a typical workroom. Uniformity of air distribution through the perforated metal acoustical ceilings and uniform light distribution from the pressed steel coffers recessed in the ceilings make it possible to re-arrange desks or whole departments at any time in the future as the life insurance company's varying needs require. There will be no occasion to revamp the duct work, the lighting fixtures or the rubber tile flooring. This is one of the many illustrations of foresight on the part of the building committee, the architect and the consulting engineer. It is interesting to note that the acoustical material in the ceilings was placed on the under side of the slab of the floor above to limit transmission of heat through the floors and simplify access to the piping and mechanical equipment within the ceilings

eral work areas the system is controlled in accordance with zones corresponding to the sun exposure and the air is delivered through perforated ceilings. The ceiling construction differs from the usual in that the sound absorption material was placed in the under side of the slab of the floor above. This method was selected in order to limit heat transmission through the floor and to make the systems less dependent on the tightness of plenum spaces, as well as to provide easy access to various piping and mechanical equipment situated within the ceiling.

Individual control of temperature is provided for the private offices on the sixth floor by means of booster heaters in the individual air ducts. Air delivery in this area is upward at a slight angle from the window sills. A portion of the basement is air conditioned by a separate coil surface unit and rough storage space in the basement is ventilated but not conditioned.

The main exhaust fan at the seventh floor draws air from various floors and automatically discharges it outdoors or back to the conditioning apparatus, as required. Air from outdoors, together with a portion of the return, passes through suitable preheaters and then through an electrostatic precipitator where from 85 to 90 per cent of all dirt is removed. This equipment was selected to remove smoke particles, which cannot be effectively removed with ordinary filters, as well as the air borne dirt and pollens usually present. The 182 cells of the precipitator have a total capacity of 124,000 cfm of air.

The outside and return air mixture passes through an air washer where moisture is removed or added as required. In the summer, cooling is simultaneously effected. Copper was used in the construction of this air washer in view of the importance of continuity of service but it was not considered necessary to use copper for the washers in the auditorium and basement systems. The treated air leaving the washer then passes directly to the main supply fan and to the fan on the south zone system. The main supply fan unit supplies treated air to seven local recirculating fan units, in which the conditioned air and filtered, local recirculated air are mixed to form the total supply for the particular zone served. In all there are 22 fan units for supply and exhaust.

Refrigeration is provided by three "Freon" compressors—two 4 cylinder, 260 ton and one 2 cylinder, 130 ton machines—which are driven by 4000 volt synchronous motors of 300, 300 and 150 hp. Each of the four cylinder machines is directly connected to its own evaporator and condenser and the two cylinder machine may be used in conjunction with either evaporator and condenser unit. By opening suitable valves the entire plant may be made to operate as one unit. Thus the failure of any one piece of equipment would not seriously impair the functioning of the building. Heavy equipment in the machine room is insulated against vibration and noise by floating foundations and isolators utilizing cork.

The compressors are connected with equalizing lines and a special automatic system for controlling the oil returning with the suction gas.

The compressors discharge through pulsation tanks into a pair of horizontal multipass shell and tube condensers, each 34 in. in diameter and 17 ft long, which are equipped with tubes of admiralty metal. A purger saves both power and refrigerant. There are also two receivers, each 24 in. in diameter and 16 ft long, and two spray type water coolers, 42 in. in diameter and 12 ft long. Connected to the coolers are "Freon-12" liquid pumps of 4 in. size, as well as the necessary filters and float valves.

Capacity controls on each cylinder of the compressors permit reduction of the output of any one machine in steps of 87½, 75, 62½, and 50 per cent.

In the auditorium, seating 1100, 6 ft ceiling coffers provide for the reflection of light and for the installation of high velocity air diffusers. There are 24 of these coffers. The auditorium is used for employee meetings, salesmen's schools, and similar purposes

Complete Control Installation

The control desk and switchboards in the compressor room govern the operation of the air conditioning and wall warming systems. Three panels at the left control the compressor motors, with dials on each panel indicating the direct current amperage, power, and alternating current amperage. Three panels at the right control the chilled water and condenser water pumps and auxiliaries.

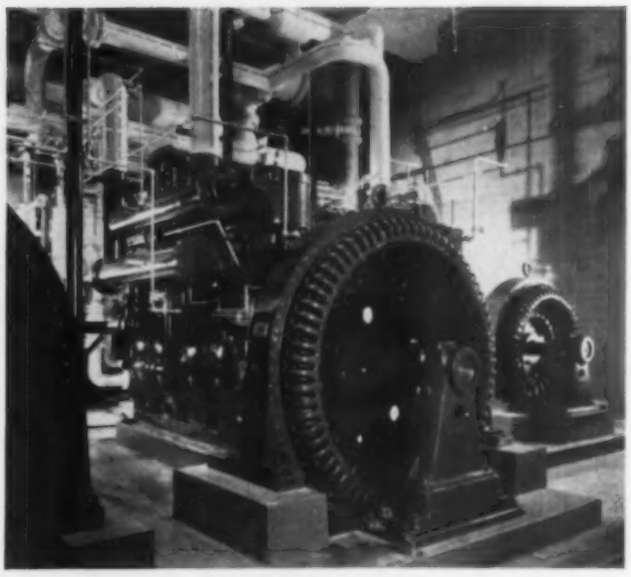
The center control section contains a panel at the lower right for the control of the following equipment: Fans, spray pumps, compressors, radiant heaters, booster heaters (for the individually controlled sixth floor system), boilers, and electrostatic air cleaning apparatus. Alongside the units on this panel are pilot lights and start and stop buttons. A master thermostat is situated at the top of this panel.

In corresponding position on the left another panel contains selector switches which enable the operator to check temperatures at key points in the apparatus and at 24 stations throughout the building. These temperatures are indicated on an electrical thermometer at the center of the control desk. This gives the operator instant and exact information at all times as to the needs of various parts of the building and just how well those individual needs are being supplied.

In this connection, it is interesting to note that the heating and air conditioning system is divided into four major zones on each floor—north, south, east, and west. Each of these zones is subject to independent thermostatic control, and this zone system allows for variations in outside temperature due to sun or prevailing winds.

The controls that govern the temperature of water through the radiant system (actually four separate systems) automatically adjust for the required temperature in each zone, in direct relation to the exterior conditions to which the zone is exposed. Similarly, the four duct supply systems are controlled automatically for humidity and temperature.

This battery of three low pressure oil burning boilers supplies the heat requirements. Rated at 185 hp each, they provide 50 per cent more capacity than the maximum expected at any time



This view shows the compressor units. The two larger compressors can be seen in the foreground and the smaller one at the right. Total capacity is 650 tons, with the larger units supplying 260 tons each and the smaller unit 130 tons. Powered by 4000 volt, 300 hp synchronous motors, the large compressors are directly connected to their own evaporators and condensers. The 130 ton compressor may be hooked up with either evaporator

Above the electrical thermometer on the control board is a recorder which keeps a running record of the following temperatures: Outside wet bulb, outside dry bulb, apparatus dew point, fan discharge and return air. The recorder was selected for these points since the trend, in addition to the momentary value, is helpful in operation. On either side of this recorder are the flow meters for condenser water and chilled water.

With the exception of the start and stop buttons for operation of the equipment, all these controls are repeated on a similar board in the building superintendent's office. In addition, his board contains a combustion recorder and dials indicating the fuel oil supply in the three storage tanks, which have a combined capacity of 16,500 gal.

The building superintendent keeps a daily log covering all conditions in the air conditioning and heating system and all conditions affecting the system. A total of 57 entries is made on this record every 2 hr.

In addition to the daily log and in conjunction with it, the superintendent prepares a daily metering record. This covers all energy, fuel and water consumption, together with the basic operating conditions during the period covered. These records will enable the company to keep an extremely accurate check on operating costs and on the best methods of handling the system for cost control.

The boiler room contains three boiler units burning bunker C oil under complete automatic control. Each boiler is provided with an operating panel showing pressure, over fire draft, and the degree of smoke. Combustion recorders for the three boilers are mounted on a separate panel. In the superintendent's office there is an instrument to indicate the smoke of the total chimney and an alarm to notify him of any objectionable smoke condition.

Photos by Hedrich-Blessing Studio

Will These Piping Changes Pay?

The Chief and Gard Check Up On Some Requests for New Valves To See If They'll Pay Out . . . By A. C. Kirkwood*

SUMMARY

When plant piping changes, sectionalizing valves, etc., are under consideration or have been requested by various departments, the piping engineer must determine whether the necessary investment is justified. The Chief and Gard—whom you met through an article in the February HPAC—analyze three specific requests, find that two of them are worthwhile going ahead with, and that the third should probably be postponed. . . . Their reasoning is given so that the same principles can be applied when similar problems come up in other plants

MORNING, Chief."

"Morning, Gard. Wish you would study these requests from Production. Let me have your comments this afternoon."

"O. K., Chief, but what is up?"

"Well, our loop header and sectionalizing valves on the steam lines to the kettles in Department D are showing the anticipated savings. You will remember that we looped the header and installed single sectionalizing valves to sectionalize the kettles in pairs. These changes cost $255 and are charged off at $51 a year. A four hour shutdown on two instead of six kettles costs us $50 rather than $150, based on $225,000 product value and a 6000 hour year. That is a saving of $49 a year."

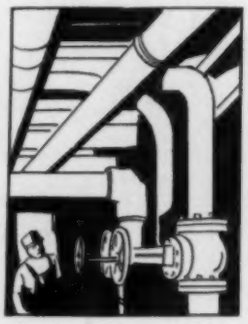
"I remember your figures, Chief, but so far in nearly nine months we have had only one outage. And that was for an hour-and-a-half to replace the gate to No. 3 kettle."

"Yes, Gard, and the boys in Production know it too. The result is several requests here and more to come for similar improvements in other departments. Now, I don't want to go out on the limb for these requests unless they are justified. The Boss is pretty well sold on the idea we worked out for Department D, but I know he won't stand hitched if we recommend some off-color ideas."

"O.K., but they will have to be way off-color, Chief, or I'll agree with these requests. Good piping layouts save time and money in the maintenance department."

* * *

Request No. 1.—Department A-3 wants the steam lines to the dryer looped and equipped with sectionalizing valves in the belief that decreased outages for maintenance will result in a saving of operating costs. Investigation of the layout shows the dryer is equipped with a number of hand regulated steam coils fed by two supply lines, one line being on each side of the unit.



With this split supply, it is possible to replace or repair valves by taking one-half the supply out of service, working the lines while they are still quite warm. Substantiating this procedure is the engineering department's statement that the remaining heating coils usually can be supplied with somewhat higher pressure steam from the reducing valve, thus permitting better than half of normal production rate during the time of repairs.

Assuming two-thirds capacity on one bank of heaters it is obvious that a $225,000 per year product value based on 6000 hours operation will suffer a loss of $12.50 per hour of outage. A check of the records shows the average time out is two hours per outage and there are four outages per year—eight hours or $100 loss per year—chargeable to steam supply valves and heating elements.

The cost of looping the far ends of supply lines, three sectionalizing valves, labor, covering, painting, department burden and other items is estimated as but $180. Retirement rate is 20 per cent, or an annual retirement charge of $36.

Splitting the heating units into four groups means that only 25 per cent of the entire unit is out of service for emergency repairs at any one time. Thus, 75 per cent is always available and this can be increased by approximately one-third in accordance with the engineering department's statement. Therefore, in case of necessity and under conditions of normal steam pressure, it is possible to carry full machine capacity while emergency repairs are being made. In accordance with this analysis, no appreciable product loss is to be anticipated and the annual retirement charge of $36 is more than offset by the saving in product loss of $100—a net saving of $64 per year.

Request No. 2—Power and Steam (Department P) has its difficulties with blown gaskets and leaking valves. Boilers, engines, turbines, auxiliaries and attendant piping have been added from time to time for years as greater capacity was required. Result, a plant having but little unity of design and but minor provisions for insured continuity of service. A detailed description of this plant layout would require a lengthy volume; but, since it is typical of so many plants, a few comments on obvious disadvantageous items will suffice.

The plant contains eight boilers of assorted sizes and types. All are required to meet demands during the busy season, but when the factory shuts down for the week-end several units are banked. The combination of temperature changes, age and design of the steam lines in the boiler plant and factory supply lines leads to occasional blown gaskets. Then, too, some of the gate

*Associate Engineer, Burns & McDonnell Engineering Co.

valves fail to seat tightly. Repairs are delayed until the week-end when possible, even though steam leaks are of considerable proportion. Tenacity and ingenuity have kept the steam plant on the line with but few exceptions until these week-end repair periods are reached.

Of course the biggest part of the factory went out of production one Monday morning when the bonnet gasket blew on the gate valve on No. 5 boiler steam lead. It was the largest boiler in the plant at the time. By the time the other boilers were shut off and banked and the maintenance crew had the gasket replaced it was most noon. Oh yes—the factory employed nearly 500 men then.

Then there was the time when the non-return on No. 2 had to be repaired. The gate valve refused to close tight in spite of repeated trials. Well, the load was piled on day and night and no way to get at that valve until the week-end. When it was opened up the seat and disc face were found to be badly chewed up. A replacement valve could not be obtained until early in the week. The factory ran on reduced schedule all that next week—with plenty of unusable heat coming from the sales division!

". . . and what we need right now while there is an opportunity to put it in before the heavy load season is some sectionalizing valves and a loop on the main steam lines in the boiler and engine room. The exhaust and extraction headers should have similar provisions. The boilerfeed suction lines should be fixed so that they can be split in two sections—the valves and joints being so small that repairs can be made rather quickly in an emergency. The boilerfeed discharge headers, regular and emergency, should also be split and looped as a single header."

An analysis of these requests indicates a cost of some $25,000, or an annual write-off of $5,000. Assuming about four hours to repair the trouble, the product value would have to be some $7,500,000 per year. On top of that, one complete shutdown per year is not in the realm of expectancy.

Further investigation of the layout requested shows where modifications will materially reduce this cost. For instance, the four oldest and smallest boilers can be considered as one unit, the next oldest pair as another unit. The two newest and biggest boilers should be treated individually. Since the feedwater has two paths, main and emergency headers, it is not necessary to loop them. The exhaust and extraction steam headers should have but one sectionalizing valve each, thus splitting the factory as to steam supply. On this basis the estimated cost of the improvements is reduced to $10,000. This indicates $2000 per year write-off, and some $3,000,000 annual product value. The plant produces more than double this value of product each year, therefore the improvement is worthwhile.

Request No. 3—The steam presses in Department C are a comparatively new installation. They were installed in the old so-called finished products building next to the power plant so that steam at high pressure and temperature would be available. Wisely enough, two independent steam lines were run to supply the four machines, two on each line. Of course one reason was that operating requirements require the piping to be in the clear, the proper place being back against the wall.

Department C wants these lines looped and sectionalizing valves installed to isolate individual units. To do so means cutting a heavy reinforced concrete floor, installing a heavily covered concrete trench, pipe with double thick covering, a trap with drain lines and the valves. The estimated cost of this new material, installed, is $1250 and the annual write-off of 20 per cent would be $250.

The annual department product value is $480,000, or an average of $120,000 per machine, according to the cost division. Based on a 6000 hour year this is $20 per hour. Two machines out cost $40 per hour.

Operating records for the short time the units have been installed, plus records of similar installations, show that one outage per year is about the worst that can be expected—this in spite of the fact that machine gate valves are closed and opened numerous times each week when new dies are installed. When out of service to repair valves it means a shutdown of not over three hours. Thus the three hour shutdown under present conditions causes a loss in product output of $120. Under the requested revised piping layout this would amount to $60. Obviously, the saving of $60 per year will not pay for the annual write-off of $250.

* * *

"Hello Gard. As long as I was near your office I thought I'd drop in to see how you are progressing in your study of those requests for additional piping."

"Well, Chief, unless I have some errors in my arithmetic I have the answers ready for you. Department A-3 wants just what we gave Department D. I figure that an investment of $180 will save $64 a year and that is a good return in anybody's language."

"Hmm——even if Engineering is wrong as to raising the capacity of these heaters for short periods, we still have a good picture. Next?"

"Well, Chief, the request of Power and Steam is well founded but not so easy to set up in black and white. I don't think their entire request should be allowed because it demands an expenditure of $25,000. If the request is modified a bit, it fits the main idea almost as well and cuts the installation cost to about $10,000. This requires an annual write-off of $2000. Any of the big valves will take four to eight hours to repair—at four hours it is equivalent to $500 per hour in product value. This is about $3,000,000 per year in terms of product, or less than one-half our normal output. There are a few valves and joints in the power plant that can force a shutdown of half the factory. While all the changes are not to prevent a shutdown of half the factory, nor do we expect such occurrences each year, still the potential saving is high enough to be in the picture. I suggest approving the modified plan."

"All right, let's have the last."

"This one is not so hot, Chief. Department C wants piping worth $1250, costing $250 a year to retire. The best saving they could make is $60 a year. I cannot see value in the requested improvements, nor can I see an alternative layout until more presses are added. At that time some arrangement may be desirable."

Air Conditioning Attracts Tourists

Helps New Orleans to Be Summer Resort

By P. J. Rinderle*

IN recent years New Orleans has been host to an increasing number of summer tourists. A great amount of this heavier summer traffic is, of course, attributable to the widespread use of the automobile over splendid highway systems. But that is only part of the story; air conditioning has also been a factor.

New Orleans is one of the nation's great winter resorts because of its semi-tropical climate (average temperature October through March is a comfortable 60.7 F); it is also in many respects a summer resort in spite of this same semi-tropical climate, for the summer average temperature is 78.3 F. Furthermore, in the past 68 years the temperature has gone above 100 only 14 times. Man, however, in his ceaseless striving for an ideal and a comfortable existence has done with air conditioning that something about the weather that baffled his ingenuity since time immemorial. New Orleans was willing to make a concession to regulated weather and unhesitatingly gave the palm of victory to the machine over nature.

New Orleans has about 400 air conditioning installations exclusive of residential units. Included in the business and commercial installations are 12 office buildings, some of which have more than 20 stories; besides providing conditioned air for their offices they serve also the many shops and stores in the building.

The summer visitor to New Orleans can arrive in the city in an air conditioned train or bus and stay at one of the 37 hotels that have installed units. Shopping can be enjoyed in about 100 stores of all kinds, including the huge department stores, while the amusement field offers air conditioned theaters, radio stations, and the 12,000 seat municipal auditorium. Other classes of structures that have installed air conditioning are beauty and barber shops, brokers' and real estate offices, churches, civic buildings and clubs, hospitals, doctors' and dentists' offices, many general offices, funeral parlors, industrial plants, restaurants and telephone exchanges.

While greater interest in residential air conditioning is being manifested, installations are being placed at a moderate pace. This is due to a large extent to the less expensive attic and room ventilation units that are very popular and extensively used throughout the city. New apartment construction, however, involves the use of air conditioning and many of the finer homes have units installed or are being built with that ultimate purpose in view.

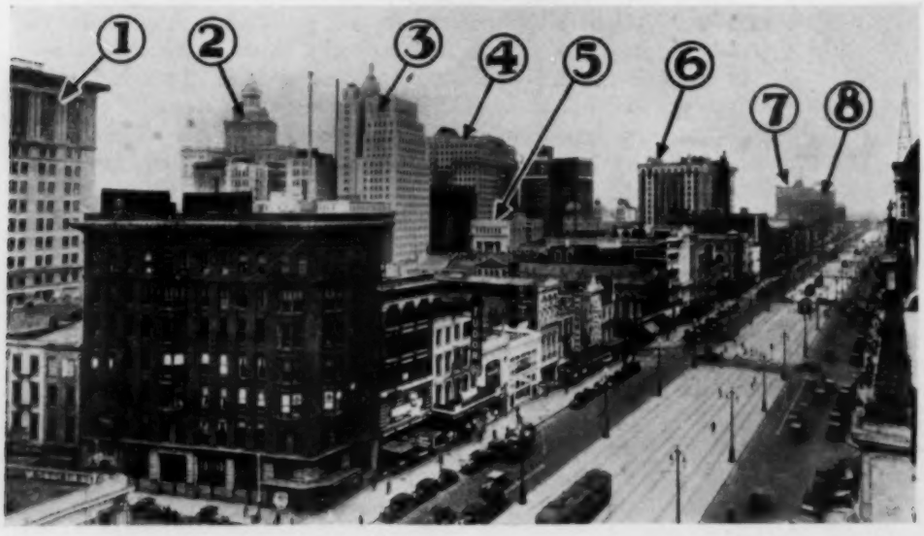
The following comments of New Orleans business people are further evidence of the advantages of air conditioning:

William G. Zetzmann, chairman of the convention and visitors bureau—One of the most effective steps taken by New Orleans to increase the crop of summer visitors was to air condition its municipal auditorium. As a result, New Orleans has taken on added importance as a center for large summer conventions because the delegates to such conventions realize the advantages and the comfort of meeting in an air conditioned building. Air conditioning of our auditorium has also stimulated added interest in concerts and other functions during the summer months.

George Riley, manager of the Roosevelt hotel—The Roosevelt hotel long ago realized the importance of air conditioning as an asset to summer tourist travel to New Orleans and consequently was a pioneer in this field. The Roosevelt was the first New Orleans hotel to have an air conditioned dining room as well as the first to air condition guest rooms. I know of unnumbered instances where air conditioning has been responsible for summer travel to New Orleans and I feel sure that the entire city is gaining increased summer tourist travel because of the extension of air conditioning into practically every kind of structure serving the public.

Roy C. Alciatore, proprietor, Antoine's restaurant—In connection with my recent installation of air conditioning equipment in several rooms at Antoine's restaurant, I wish to state that I am delighted with the results obtained. I attribute a large increase in my summer business to air conditioning, and I have received many favorable comments from summer tourists who have recently visited Antoine's and enjoyed the added comfort. I am convinced that in a few years the public will demand air conditioning, and the shrewd business man will see to it that it is provided.

*New Orleans Association of Commerce.



Canal St. in New Orleans showing some of the buildings that have air conditioning. 1—Whitney bank building. 2—Hibernia bank building. 3—American bank building. 4—Canal bank building. 5—Federal Reserve bank. 6—Roosevelt hotel. 7—Jung hotel. 8—New Orleans hotel

The Design and Installation of a Central Hot Water Heating Plant

Heating of Chatham Park Village, Large Chicago Apartment Project, Described by C. G. Wohlfarth*

AT 83rd St. and Cottage Grove Ave., on Chicago's south side, the construction of 63 dwellings is transforming a 22 acre plot of land into Chatham Park Apartment Village. Considered the largest privately financed dwelling construction in the middle west, the enterprise consists of 39 row house buildings with duplex and garden apartments, and 24 conventional apartment buildings. It will provide living accommodations for 554 families; 160 five room, two level apartments and 76 three room garden apartments will be contained in the row houses, and 12 five room apartments, 123 four room, two bedroom apartments, 78 four room, one bedroom apartments, and 105 three room apartments will be housed in the conventional buildings.

The residential area will occupy a ground space of 845,000 sq ft and provide garage facilities for 130 cars, while 140,000 sq ft has been set aside for a proposed shopping center, with provisions for a future theater and other recreational buildings. The property will be completely landscaped and have private winding streets.

Central Hot Water Heating Plant

The total heating requirement of 26,500,000 Btu per hr is supplied by a central forced circulation hot water system. The boiler plant consists of four stoker fired steel boilers cross connected into one supply header. Forced circulation is accomplished by three centrifugal

*Manager, Engineering Dept., Kehm Corp.

SUMMARY

Chatham Park Apartment Village — a large, privately financed project in Chicago—is heated by a central plant forced circulation hot water heating system. The boiler plant which supplies the heating requirement of 26,500,000 Btu per hr consists of four stoker fired steel boilers cross connected into one supply header. Water is heated to a predetermined constant temperature and is mixed with return water through valves under the control of an outside compensating thermostat to govern the temperature of the constantly circulated water in accordance with the outside temperature. . . . . The water is delivered to the 63 buildings through an underground system of piping covered with factory presealed insulation and laid in earth trenches. . . . . The 63 buildings are divided into 13 groups, each having its own sub-system heating circuit. All groups (except one which is supplied directly from the boiler house) are connected by two main distributing systems, one for the north half and one for the south half. Pressure differential valves in each group circuit supply main prevent excessive circulation. . . . . Final delivery of the water to the convection heating units is accomplished through a system of single main circuits in which special shunt fittings are installed. Each circuit is fitted with a square head cock at the return for adjusting circulation, and plugged tees are provided for connecting a flow meter to measure the flow. . . . . Except in the bathrooms, copper convectors of the concealed type are installed throughout; they have serpentine elements arranged for two or three pass circulation. Cast iron concealed radiant convectors heat the bathrooms, the radiant heat given off from their "live" fronts being the determining factor in their selection. . . . . Domestic hot water is generated the year around by boiler water being circulated through two shell and tube heaters

pumps arranged so that two will be in constant service with the third as a standby. Water will be heated to a predetermined constant temperature under manually adjusted aquastat control. Communicating with the supply header, a motor operated three way mixing valve is installed at the discharge of each pump. Through these valves a proportionate quantity of cool water returning from the distributing system is bypassed into the supply header where it is mixed with constant temperature boiler water. The temperature of the mixture is determined by an outside compensating thermostat which controls the operation of the mixing valves. By this method, the temperature of constantly circulated water is varied in accordance with the outdoor temperature. Wasting of heat and overheating of buildings is thus prevented.

As a further means of increasing the plant efficiency, each boiler is fitted with three return tappings to prevent possibility of short circuiting and assure complete circulation of water over both primary and secondary heating surfaces, as it moves toward the supply tapping.

Full automatic draft control is provided, along with smoke indicators and also indicating thermometers on all supply and return heating circuits, all mounted on a boiler room panel.

Underground Piping System

Tempered water is delivered to the buildings through an underground distributing system containing more than four miles of piping. All piping installed below grade (except that which passes through basements and crawl spaces) is covered with factory presealed insulation and was delivered to the site in standard lengths. The covering consists of a layer of 85 per cent magnesia insulation protected by 2 in. of high melting point asphalt and finished with a sheet metal jacket.

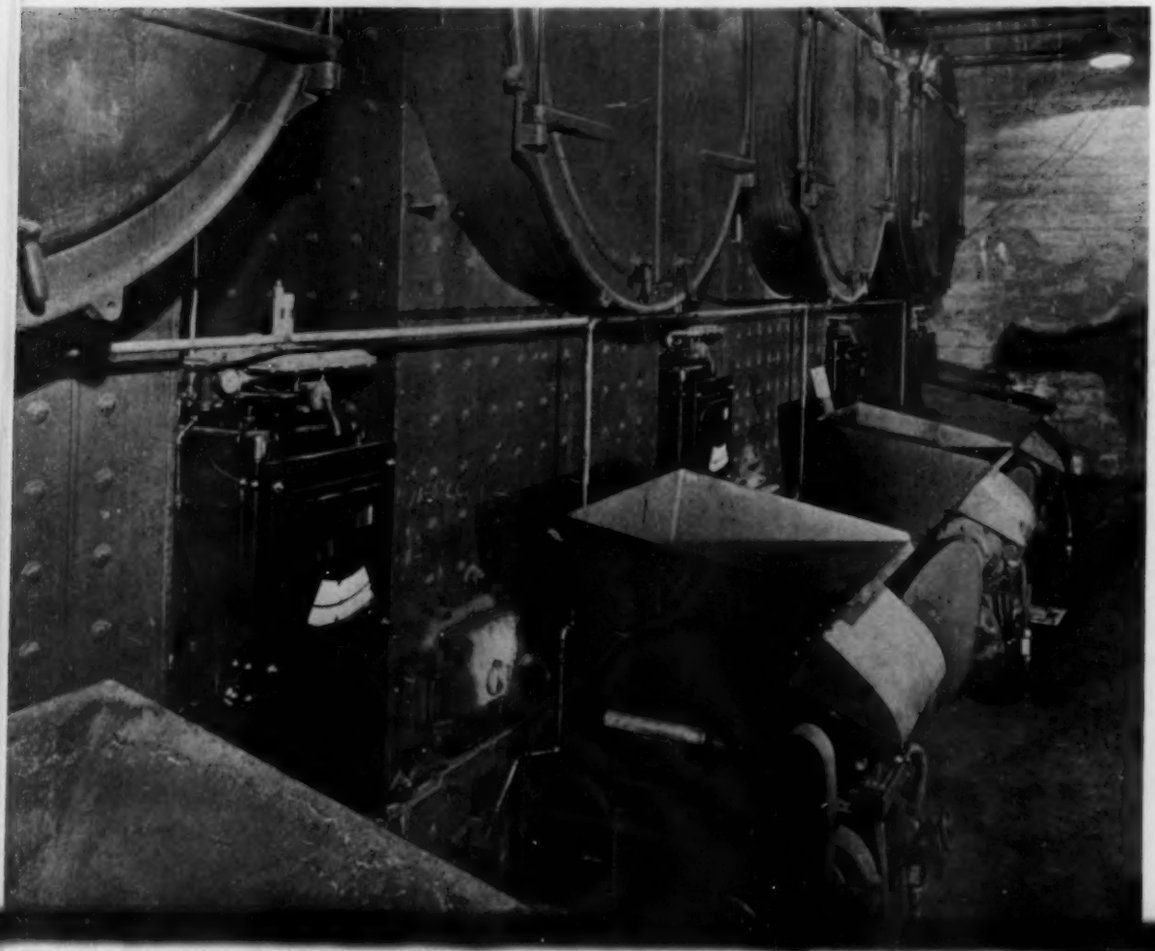
No conduits are necessary, as the piping so covered can be laid without further treatment in earth trenches.

About 6 in. of bare pipe is exposed at each end of the delivered lengths to facilitate fabrication on the job. After being properly supported and aligned in the trench, the piping is welded and covered with an equal thickness of magnesia. An outer sheet metal jacket is then placed over and extending slightly beyond the joint so as to overlap the fabricated lengths. Into a hole pierced in the jacket, asphalt is poured to complete the installation. Elbows and long radius bends are treated in the same manner and since no branch connections are taken from the distributing system except in the buildings, there should be no problem of maintaining tight insulated connections. As the piping in crawl spaces and basements is suspended from the ceiling, only the standard type of 85 per cent magnesia insulation with canvas jacket is used.

Since all branches are taken from the system in basements and crawl spaces, the problem of caring for thermal expansion is minimized. The piping is anchored at such building foundations as necessary and allowed to expand through the foundations of the succeeding buildings. By this method, the natural offset piping required to clear construction members provides adequate means of absorbing expansion. In the few cases where it is impossible to take advantage of this feature, prefabricated expansion loops are installed. As all such loops are situated in the narrow crawl spaces of row house buildings they have a corrugated inside radius to provide equal deflection with less perimeter than that of the ordinary bend.

Separate Circuits for Building Groups

The 63 buildings are divided into 13 groups, each having an independent sub-system heating circuit arranged for reversed return circulation. With the exception of one group of buildings (which, because of



The total heating requirement of 26,500,000 Btu per hr is supplied by the forced circulation hot water system, the boiler plant for which comprises four stoker fired steel boilers. The four boilers are cross connected into one supply header. In summer, one of the boilers generates the domestic service hot water

its location, is supplied directly from the boiler house) all group circuits are connected by two main distributing systems, one supplying approximately the north half and the other approximately the south half.

For economy of installation, the north system is of the direct return type, and any tendency toward unbalanced circulation is overcome by the use of pressure differential control valves installed in each group circuit supply main (except for the group farthest from the boiler house). A pilot line extending from the valve to the circuit return main at its terminal point meters the pressure drop in this circuit and acts upon the valve diaphragm. The properly adjusted valve, thus controlled, acts as a variable orifice to impose whatever additional resistance is required in each group circuit, in order to prevent excessive circulation at any point regardless of fluctuations.

In contrast to the north system, the building groups comprising the south half, being arranged in the form of a rectangle, are supplied by a reversed return system. The inherent ability to retard the flow of water through every path taken in this system with nearly equal resistance eliminates the necessity of installing the pressure differential valves. Lubricated square head cocks are situated at all junction points of the circuit and distributing system returns so that additional manual adjustments can be made.

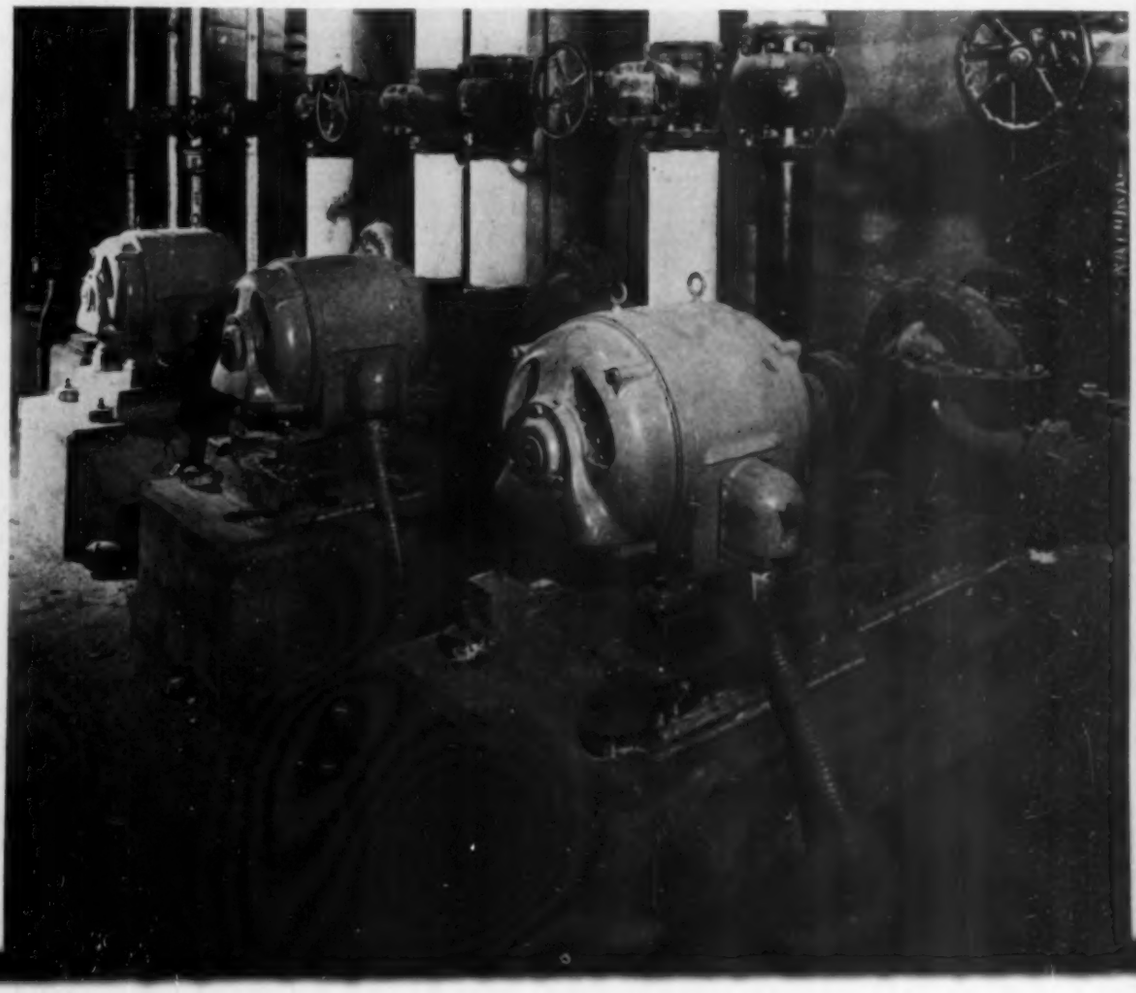
At every point where the supply and return mains are lowered from the basement ceiling to underground elevation, air is removed through manually operated vents; this will eliminate about 50 per cent of the air from the system before it finds its way into the room heating units.

Single Main Building Circuits

The final delivery of water to the various convection heating units is accomplished through a system of single main circuits in which special shunt fittings are installed at all supply and return connections. Consisting throughout of only two sizes—either 1¼ or 1½ in.—each circuit is fitted with a square head cock at the return to regulate the flow. Proper regulation is made possible by the installation of plugged tees at the supply end to which a flow meter can be connected. Between the tees, a gate valve is installed which, when closed, will allow the water to flow through the meter. Adjustment of the square head cock at the return can then be made until the allotted flow of water is registered on the instrument.

As the pipe diameter of a single main circuit remains constant throughout its length, the method by which these systems were designed and sized is worthy of mention. A pair of given size shunt fittings, consisting essentially of a special tee and metal insert, arranged for proper supply and return diversion, possesses a given diverting head, expressed in feet of water, for every constant quantity of water flowing through the main. This principle, embodied in the manufacturer's performance chart, provided the first step in sizing the system—that of determining the available head corresponding to the required flow of water in each 1¼ in. or 1½ in. circuit. From this quantity, the pressure loss through the largest third floor convector was subtracted, leaving the balance to overcome the resistance in the riser and branch piping.

In order that the pipe sizing tables in the ASHVE's Heating, Ventilating, Air Conditioning Guide could be used, this remaining quantity was then converted to milinches. Elbows and fitting resistances, expressed in equivalent feet, were added to the actual length of piping to the third floor and this total was divided into the milinch quantity to arrive at the unit resistance, by which the convector connections could be sized. The shorter equivalent lengths of piping to the second and first floors



Forced circulation is accomplished by these three centrifugal pumps arranged so that two will be in constant service with the third as a standby. A motor operated three way valve at the discharge of each pump enables varying the temperature of the constantly circulated water in accordance with the outside temperature

Copper convectors of the concealed type are used throughout, except in bathrooms. The sheet metal enclosures are made with latch type removable fronts to permit ready inspection of the heating elements and air vents and cleaning of the enclosures

Cast iron concealed radiant convectors are used in the bathrooms. Radiant heat emitted from their "live" fronts is expected to prevent discomfort from evaporative cooling of exposed skin surfaces and was the determining factor in selection of the units

were also divided into this same quantity and the correspondingly higher units of resistance were determined by which the respective connections could be sized. By this procedure, excessive circulation through the first and second floor convectors is prevented, since a separate set of capacities is determined for each floor.

No pipe covering is installed on the single main circuits or branch piping, so that the heat given off will aid in warming the laundry rooms and prevent cold floors over crawl spaces. To provide complete concealment of piping in the row house garden apartments, two circuit mains are installed. One main is situated in a crawl space one-half of the width of the building and extending longitudinally from end to end under the living quarters. The other main, taken from the distributing system in the crawl space, extends across the kitchen in a furred beam and is then exposed in the laundry, which occupies the opposite half of the buildings.

Convectors of Special Design

Except in bathrooms, special copper convectors of the concealed type are installed throughout; they comprise a complete sheet metal cabinet with built-in insulation, and are fitted with a latch lock front for easy removal to facilitate inspection of heating elements and vents, and cleaning.

The unit differs from the ordinary type in that it is equipped with a serpentine heating element made up in 3⅝ in. to 5½ in. depths. The tubes are arranged for two pass and three pass circulation, respectively, and are metallically bonded to copper fins. Since there is only one tube (instead of two or three) all of the water must pass through it with a considerably increased velocity over that which would otherwise be the case. The resulting turbulent action increases the heat transfer efficiency so that a lower volume of water is required for the same heat emission. Considering the number of convectors required, this has an important bearing on the continuous pumping load and current consumption. Air venting problems are simplified because entrained air entering the unit is rapidly directed to the air chamber at the return connection and prevents air stagnation in the element itself.

Cast iron concealed radiant convectors are installed in the bathrooms. Radiant heat emitted from the "live" front, with resulting decrease in the required amount of air convection, is expected to prevent discomfort from evaporative cooling of exposed skin surfaces and was the determining factor in the selection of this type of bathroom heating.

Supplying Domestic Hot Water

Year around domestic hot water is generated by the heating plant boilers. Boiler water is circulated through two shell and tube heaters under forced circulation by a small centrifugal pump. The operation of the pump is automatically controlled by an immersion aquastat in the storage tank to maintain the supply at uniform temperature. In this manner the pump not only provides rapid circulation through the heaters, but also acts as a valve to prevent overheating of the water.

During the summer period, only one boiler at the end of the line will be kept in operation.

Both supply and return headers at this boiler are equipped with gate valves for the purpose of isolation and a separate expansion tank line is connected to the isolated portion. The temperature of the boiler water during the summer will be maintained at about 160 F, as only a 20 deg temperature difference is needed with forced circulation through the heaters.

The consulting engineer for the project is Oscar W. Dauber and the heating system is being installed by Advance Heating and Air Conditioning Corp. The architects are Shaw, Naess & Murphy.

Hotel Guest Room Air Conditioning Requires Good Engineering Design

Warren D. Lewis, Chief Engineer of the New Yorker, Tells Why Bedroom Installations Tax Ingenuity of the Designing Engineer

SUMMARY

While air conditioning of public dining rooms and ballrooms in hotels follows more or less along standard lines, the air conditioning of guest rooms or bedrooms presents an altogether different and more difficult problem; it is one which taxes the ingenuity and resourcefulness of the designing engineer, and each job is apt to require a different solution. . . . . Noise must be given careful consideration, for such faint and almost imperceptible sounds as the hissing of air passing through a grille or the swish of air from a room conditioner may be cause for complaint from a guest. . . . . Portable air conditioning units are not the solution to the large hotel installation, Mr. Lewis believes, but are a desirable addition for cooling a few rooms. The most desirable system, in his opinion, is one in which cool air is distributed to a group of rooms, which may be on the same floor or several floors, the former scheme being preferable. An important consideration in selecting the type of central conditioning plant is the existing ceiling height, and affects either the use of cold air or cold water for distributing the cooling effect to the conditioned spaces. . . . . At the Adolphus hotel in Dallas, eight floors were conditioned and two unit conditioners were installed on each floor supplied with chilled water from a refrigerating plant in the basement; each of the units serves approximately 16 guest rooms. As ceilings in both rooms and corridors were 10 ft high, supply ducts were installed in the corridors and allowed new corridor ceiling heights of slightly over 8 ft. . . . . Two ducts were run down each corridor, giving individual air supply to each side and preventing "cross-talk" through the ducts between rooms on opposite sides. A desirable feature of this scheme is the ease of controlling the air conditioning on any one floor, as in hotel operation it is sometimes necessary to place a floor "out-of-order" for house cleaning, painting, etc. . . . . A novel feature is a thermostat controlled splitter damper on the corridor ducts, which by governing the air circulation takes care of differing sun effects on opposite sides of the building. . . . . Importance of complete control of temperatures and humidities cannot be over-emphasized; neither can the necessity of the proper gages and instruments to aid efficient operation. Cost of the control equipment for the Adolphus installation ran 5 per cent of the total job cost, and the total was about $400 per room. Total cost per occupied room, including all operating expenses, averaged 33 cents a day over a four months' period, and as the room rates were raised 50, 75 cents and $1.00 per day, the hotel was able to pay the additional operating cost, amortize the investment, and make a fair profit

A PROBLEM of prime importance in the air conditioning of hotel bedrooms or guest rooms is that the slightest noise may be noticed and complained about by the guest. As a rule, it isn't the moderate street noises that cause trouble, because to get the full benefit of the air conditioning the guest necessarily sleeps with all windows closed. It is rather those faint, almost imperceptible noises—such as the slight hissing of air passing through a grille or the swish of air from a room air conditioner fan—that make the trouble and cause some guests to "raise Cain." Woe to any designer who overlooks or dismisses as inconsequential this problem of duct, fan or grille noises.

Use of Portable Air Conditioners

Up to the present, guest room air conditioning has been confined almost exclusively to existing hotels; before any consulting engineer can decide the details or even the type of system he plans to install he must necessarily make a survey of the building and find out what space is actually available for machinery, ductwork and piping or take a chance of running up the cost of his job to a prohibitive figure. However, if the hotel management decides to experiment with a few rooms (especially if these rooms are widely separated) the self-contained air cooled conditioner offers excellent possibilities.

It seems to me that portable air conditioners got off to a bad start in hotels several years ago when they were water cooled and their mobility was limited, for each move meant a new water and waste connection. We installed a number in the New Yorker and they stayed put in the original rooms. Another objection was that they had to be placed near the available water and waste in each room instead of in an unused, out-of-the-way corner; too, the cabinets themselves were quite large for the average hotel guest room. The introduction of air cooled portable conditioners has eliminated the need for water and waste connections, but these units are naturally larger and have to be set in front of a window; in rooms with but one window, this is a serious objection. My own experience has been that anything less than a ¾ ton job will not properly air condition the average size hotel room in real hot weather in New York City, and this size requires a rather bulky cabinet at the best. Another objection in the past has been the noise created by the compressor, motor and fan. Manufacturers have insulated against machine noise and have done a good job, but in some units slight air noises from the circulating fan are annoying to some guests, especially at night.

Frankly, to my way of thinking, portable units are not the solution to a large air conditioning job, but are a desirable addition where a hotel desires to cool a few of its rooms.

Many Types of Central Systems

Central systems for guest room air conditioning are installed in numerous ways, largely according to the ideas of the consulting engineer and the limitations of the building. One of the first installations I recall circulated the refrigerant to unit coolers in the individual rooms. Confining the refrigerant and all the equipment which goes with it to the basement is good practice, in my opinion.

For air conditioning large groups of guest rooms, such as an entire floor or a number of adjacent floors, there are two desirable methods of distributing the cooling effect; by cold air or by cold water.

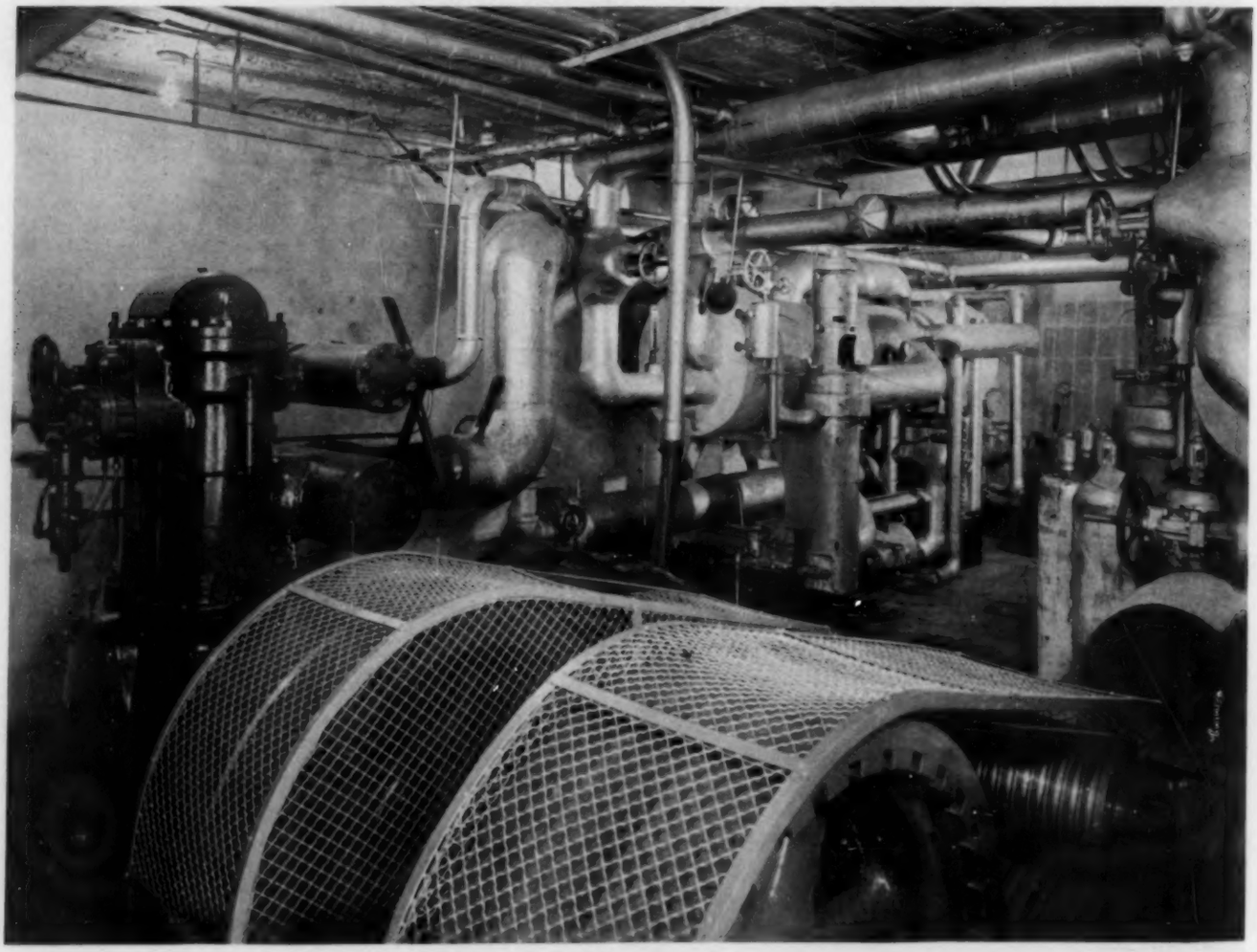
The main objection to using cold air is the space required by the ducts, especially if the coolers and fans are in the basement. However, a few years ago a successful installation along these lines was made in a Texas hotel. The fan to circulate the cold air for the entire building was situated in the basement and the riser was installed in an unused elevator shaft. This method requires ample ceiling height on all floors for duct installation, and where ceiling heights are less than 9 ft, cold water distribution to cooling units in individual guest rooms seems the apparent solution. However, a system of cold water risers may present an installation problem in finding available space for the risers themselves; running the necessary horizontal supply and return piping through low or crowded ceilings may also be difficult. Then again, piping used for circulating the chilled water has to be properly covered, and the outside diameter of the right thickness of covering for "ice water service" is considerable. Installing not alone the pipe but the covering so it is air-tight is not always an easy problem in an existing building.

The most desirable system where the ceiling height permits it, is one in which cool air is distributed to a group of rooms from a central unit, in my opinion. The rooms may be on the same floor or on several floors, as was successfully tried out in a St. Louis hotel a few years ago, although, except for ease in installation, I fail to note any advantage in the latter method and prefer to have all rooms served by one conditioning system on the same floor.

How Adolphus Rooms Are Conditioned

About four years ago, I was detailed to get out plans and specifications and then take bids for air conditioning 250 guest rooms in the Adolphus hotel at Dallas. I

One of the compressor units at the Adolphus, showing the condenser, water cooler, etc. At the rear, although hidden by the piping and other equipment, are the condenser water circulating and chilled water circulating pumps. The electrical starters for the compressors are outside the picture to the left. All the condenser water and chilled water piping is welded steel to insure a tight job. The designer was liberal in the installation of thermometers, and they are used both on the suctions and discharges of the compressors as well as the inlets and outlets of the condensers and water coolers. Five are shown in this photo



was later privileged to return to Texas to let the contract for the complete air conditioning job and remained for several months to supervise the installation and start up of the system. The following is a brief outline of the installation.

It was decided that the refrigerating plant which would be used to chill the water that was to be the cooling medium would be situated in the basement. Two motor

The Adolphus uses its cooling tower to advertise its air conditioning. It is 60 ft long, 28 ft high and 16 ft deep; the five fans are 84 in. in diameter. Two of the fans are driven from the air conditioning switchboard, as two-fifths of the tower capacity is used for air conditioning, and the balance is for the main refrigerating plant. There are two spray headers, one for the air conditioning plant and the other for the refrigerating plant

driven "Freon" compressors, complete with the necessary shell and tube type condensers, water coolers, etc., were selected, each compressor being equipped with electrically operated unloading valves capable of reducing the machine output to 50 per cent of its rated capacity. The unloading valves are used to vary the compressor capacity so as to maintain (under thermostatic control) a chilled water temperature of from 40 to 45 F. Two motor driven chilled water centrifugal pumps circulate a constant quantity of water from the basement to all the unit air conditioners on the guest floors above, and the control of both temperature and humidity of the air discharged from each unit conditioner is obtained by automatically controlling a bypass damper on each unit conditioner.

There were eight floors to be air conditioned and two unit conditioners were placed on each floor, each one large enough to supply approximately 16 guest rooms. To provide maximum motor reliability in the operation of these unit conditioners, the 1½ hp fan motors regularly supplied were replaced with 2 hp motors. The extra cost was considered good "insurance"; in fact, all motors used for driving the compressors and water pumps were loaded only to 90 per cent of their rated capacities under maximum load conditions, in accordance with the specifications. The unit conditioners have 25 per cent more air capacity than would normally be considered necessary, and this surplus air is used to ventilate each bathroom through a grille opening cut in the bathroom pipe riser shaft; this prevents odors from entering the sleeping rooms and (incidentally) saved the cost of installing a bathroom exhaust fan as originally contemplated.

Outside air ducts to the individual unit conditioners were installed of sufficient cross-section area to permit the use of 100 per cent outside air through the conditioners, this (as well as the recirculated air) being drawn through unit type viscous filter banks at low velocities.

As the ceilings in both rooms and corridors were 10 ft high, air supply ducts between the conditioners and the guest rooms were installed in the corridors of sufficient size to give low air velocities and still permit of new corridor ceiling heights slightly over 8 ft. Two ducts were run down each corridor, giving individual supply to each side and preventing "cross-talk" through the ducts between rooms on opposite sides of the corridor. Each guest room was equipped with a grille over the door of the corridor entrance to permit the circulated air to enter the corridor and be drawn back to the conditioner. The air is supplied to the room through a grille equipped with a louver damper operated by a knob on the wall below so that the quantity of air to any bedroom can be cut down or shut off by the guest if found desirable. In case too many guests shut off their air supply dampers at the same time so that the air pressure in the air duct increases slightly, a static pressure damper in the fan discharge opens and prevents any pressure build-up which might cause the grilles on the air outlets in other rooms to whistle.

One of the desirable features of this system is the ease in controlling the air conditioning on an individual floor. Should it be decided to put any floor "out-of-order," it is only necessary to shut down the small air circulating fans on each of the two floor conditioners; all air conditioning then ceases. In hotel operation this is a necessary control, for when a floor is out-of-order for house cleaning or painting, air conditioning is not required.

Good Control Essential to Success

One of the features which has made the installation a success is the thermostatic control system. Every device was selected and installed which would make this complete, and it also includes the loading and unloading of the capacity valves on the refrigerating compressors. There is an outdoor wet bulb control on the temperature of the circulated cold water to the floor conditioners for maintaining the proper humidity. Another novel feature is the splitter damper on the two ducts

running down each corridor. This is controlled by two thermostats in the corridor which are influenced by the return air from the rooms. When the sun swings around on the west side of the building and the return air from these rooms is consequently at a higher temperature than that from the rooms on the opposite side of the corridor, the combined action of the two thermostats causes the splitter damper to swing to the side and permit more cool air to circulate through the warmer rooms. The sun load is taken care of effectively in this way.

Instruments Permit Intelligent Operation

To assist in the operation of the system, the usual pressure gages were installed on the discharge outlets of the chilled water and condensing water circulating pumps and the suction and discharge outlets of the compressors. In addition, indicating thermometers were installed on the inlet and outlet water lines of the condensers, the shell and tube chilled water cooler, and on the suction and discharge of each compressor. A recording thermometer charts the inlet and outlet chilled water temperatures and a wet and dry bulb recording thermometer registers the outdoor conditions.

The electric feeder supplying the distribution panel for all the electric motors used in the whole installation has a wattmeter so that daily readings can be taken of the electricity used for operating the air conditioning system. I consider these instruments necessary for the intelligent operation of the water cooling plant in the basement. Indicating thermometers were installed in all outlet ducts of air conditioners on the various floors as a local check on floor conditioners in case of complaints from guests.

As designed and installed, this system gives real air conditioning, for it is possible to control (over a wide range of outdoor temperatures) wet and dry bulb temperatures, air movement and cleanliness of the circulated air. The final adjustments were made to give a dry bulb temperature that varies up and down in proportion to increases or decreases in the outdoor temperature and still to maintain a relative humidity of around 50 per cent. The importance of a complete thermostatic control system for maintaining proper room temperatures and humidities cannot be over-emphasized.

Cost of Installation and Operation

In the job in question no expense was spared to install what was considered the best and most complete control system needed. Cost of the control equipment amounted to about 5 per cent of the total job cost. The air conditioning system was installed at a cost of approximately $400 per room. Some cost figures covering a four months' period when the air conditioned rooms were first made available to the public are given in Table 1. The occupancy averaged about 78 per cent for the period and many times held at 85 per cent when the outdoor temperature climbed. The figures show that the total cost per occupied room, including all operating expenses, averaged 33 cents per day. Room rates were advanced 50, 75 cents and $1.00 per day so that over the year the hotel was able to pay the additional operating cost, amortize the investment and still make a fair profit on the air conditioning investment.

Table 1—Air Conditioning Cost in Dollars per Room per Day Over a Four Months' Period

	Occupied	Available
Operating		
Payroll	$0.0205	$0.0159
Electricity	0.1470	0.1140
Water	0.0024	0.0019
Materials and supplies	0.0406	0.0315
Depreciation	0.1189	0.0922
Total	$0.3294	$0.2555

Note: "Available" rooms are the total number of bedrooms which are in order (ready for guest occupancy) and in use. "Occupied" rooms are the actual number of rooms in use by guests. The ratio of the occupied to available rooms gives the "per cent occupancy."

There is no doubt that the general public will pay a little more for comfort when air conditioned guest rooms are available, but it must be remembered that the figures given here are for a geographical location that really gets hot in the summer, and the need for air conditioning extends over many months. When you try to apply the same figures to New York City, for example, discretion must be used; the cooling season is not only much shorter as compared to Dallas, but the temperature outdoors is not so high.

I would like to sum up this discussion of hotel air conditioning by saying that, while the air conditioning of public dining rooms and ballrooms follows more or less along standard lines, the air conditioning of guest rooms presents an altogether different and more difficult problem. It is one which taxes the ingenuity and resourcefulness of the designing engineer, and each job is apt to require a different solution.

[*In the June HPAC, Mr. Lewis discussed the air conditioning of public spaces in hotels, such as dining rooms and ballrooms, and the general questions of equipment location, water conserving equipment, air washer maintenance, etc.*]

Air Conditioning an Essential in Many Industrial Processes

● Complaints and rejections on manufactured paper products have been reduced to a minimum and, in many cases, sales resistance has been overcome as a result of the installation of two air conditioning units in the plant of the Mead Corp., paper manufacturers, Chillicothe, Ohio. In the finishing room, temperature is maintained at a minimum of 75 F and humidity at a minimum of 45 per cent. These conditions prevent moisture from escaping from the paper and causing curl, static electricity and other troubles which were serious before this installation was made. In the paper moistening room, temperature is maintained at 84 F and humidity at 80 per cent, as these conditions have been found satisfactory for introducing moisture into the paper with the equipment available.

● Air conditioning is playing an increasingly important role in the fruit growing industry. In one instance a Pennsylvania fruit grower effected an annual saving of $2200 on apple storage through air conditioning his own plant. The plant has a capacity of 10,000 bushels. Up to the time it was decided to air condition this plant, storage cost the owner about 25 cents a bushel; it now costs approximately 3 cents a bushel. A temperature of 35 F and a relative humidity of 85 per cent are maintained.

Radiant Heating and Cooling

F. E. Giesecke* Explains Fundamentals of Design for a Type of System Which Is Attracting Wide Interest

SUMMARY

Just as the warm ceiling in a room radiates energy in all directions, so do the walls and floor, the intensities of the radiations from the various surfaces varying directly as the fourth powers of the absolute temperatures of the respective surfaces. As a result of this continuous radiation of energy, every point in the room is filled permanently with it, moving to and fro in all directions at a velocity of 186,000 miles per second. The heat radiation follows the same physical laws as does light radiation, the only difference being that of wave length. . . . . There is no fundamental difference between so-called *radiant heating*, and heating by means of ordinary free standing radiators, save for the fact that more of the heat with the former is radiant and less is convected. Radiant heating might therefore be defined as the type of heating in which more than 50 per cent of the heat supplied by the heating element is dissipated by the radiation process. . . . . In order that a person may be comfortable, he must dissipate heat at the same rate at which it is produced by the vital processes of his body—some by evaporation, some by convection and some by radiation. Thus there are various combinations of air temperatures and temperatures of the surfaces of a room which surround him which will lead to comfort. The charts presented here show heat gain or loss by convection with various air temperatures, from which can be found—on one of the other charts—the necessary *mean radiant temperature* of the surfaces of the room. A third chart shows the proper relationship between air temperature and mean radiant temperature. . . . . Studies have been made at Texas A & M College to determine rate of heat dissipated by concrete slabs in which heating coils are embedded, and the results are briefly reported here. The studies also were carried on to determine the extent to which heating coils can be used as reinforcement for the concrete slab. . . . . Methods of installing heating coils in America and Europe are explained briefly

A PORTION of the heat from a warm ceiling in a room is radiated to the walls and the remainder is radiated to the floor. The total radiation from a plane surface in all directions is π (or 3.1416) times that radiated in a direction normal to that surface. The walls and floor absorb about 90 per cent of the radiated energy received from the ceiling and reflect about 10 per cent.

Just as the ceiling radiates energy in all directions, so do the walls and floor. The intensities of the radiations from ceiling, walls and floor vary directly as the fourth powers of the absolute temperatures of the respective surfaces. Thus, if the temperatures of the ceiling and floor are 100 F and 72 F, respectively, the intensities of the radiations are to each other as 560^4 is to 532^4, or as 98 to 80. In other words, the ceiling at 100 F radiates about 23 per cent more energy per square foot than does the floor at 72 F.

As a result of this continuous radiation of energy from every point in the surface of the ceiling, walls and floor, the room is filled permanently (day and night) with radiation moving to and fro in all directions at a very high velocity—186,000 miles per second. The only difference between this heat radiation and light radiation is that the light radiation has a shorter wave length. Light radiation is sensed by the human eye; it enables one to see. Heat radiation can be detected only when it produces a sensation of warmth or of cold in the person exposed to it. Heat radiation follows the same physical laws as light radiation; when a room is lighted by one or more lamps on the ceiling, the entire room is filled with light radiation varying in intensity from place to place. The space under a table, for example, is lighted—but not so well as the space above the table. Similarly, if a room is heated by means of heating coils in the ceiling, the entire room is filled with heat radiation—including the space under the table, which is filled with heat radiation of a lower intensity than the space above the table. Every room is permanently filled with heat radiation, just as it is with air, no matter whether the room is supplied with artificial heat or not, or, if artificially heated, whether the heat is supplied by a free standing radiator or by a pipe coil in the ceiling, floor or wall.

There is, consequently, no fundamental difference between ordinary radiator heating and *panel warming*, or *radiant heating*. The difference between these two systems of heating is one of degree only. With ordinary radiator heating, about 30 per cent of the heat supplied by the radiator is dissipated by radiation and about 70 per cent by convection. With radiant heating (the heating coils being embedded in the ceiling, walls or floor) about 70 per cent of the heat supplied by the coils is dissipated by radiation and about 30 per cent by convection. Radiant heating might therefore be defined as the type of heating in which more than 50 per cent of the heat supplied by the heating element is dissipated by radiation.

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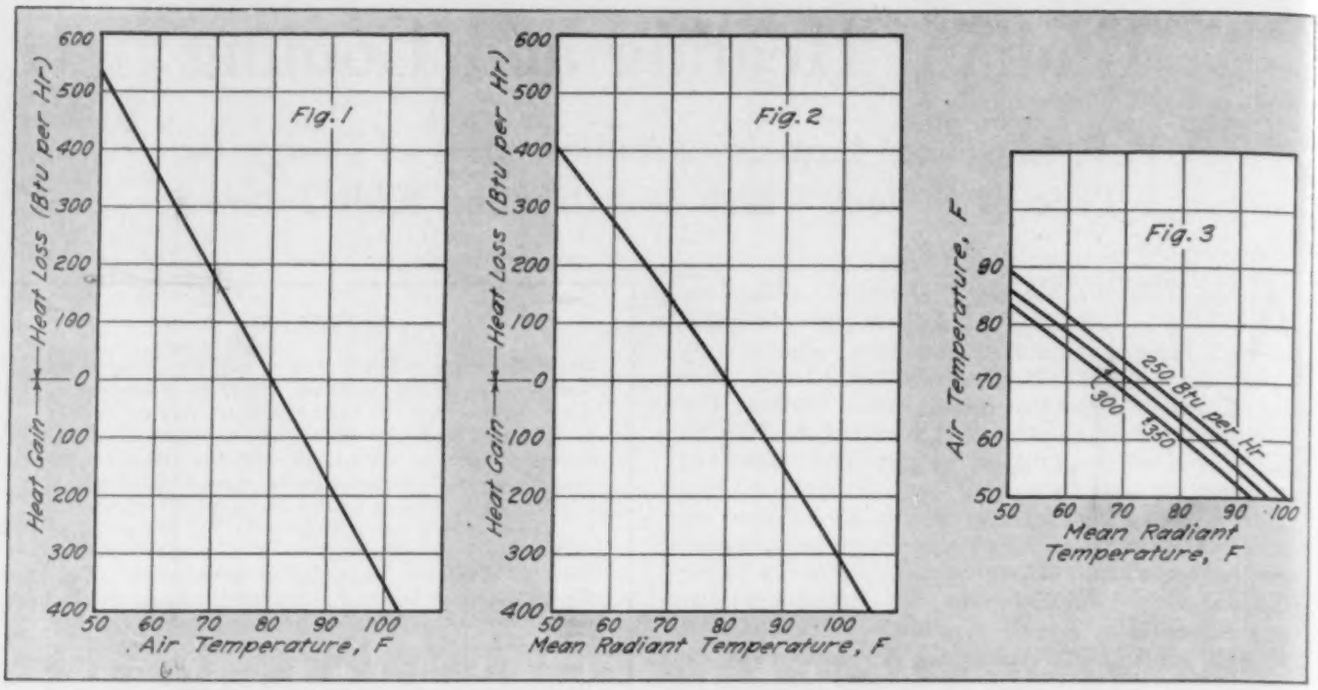
How Radiant Temperature Affects Comfort

The sensation of warmth experienced by a person in any surrounding and at any time is influenced by the temperature of the air with which he is surrounded and by the *mean radiant temperature* to which he is exposed. Mean radiant temperature was explained on p. 360 of the June HPAC.

In order that a person may be comfortable, thermally, he must dissipate heat at the same rate at which heat is produced by the vital processes within his body. An adult at rest or in slow motion produces heat at the rate of about 400 Btu per hr. Of this amount, about 100 Btu is dissipated by the evaporation of moisture from the skin or from the lungs, and the remainder (about 300 Btu) must be dissipated as sensible heat by convection and by radiation. If, for example, 125 Btu per hr is



dissipated by convection, 175 Btu per hr must be dissipated by radiation.

The quantities of heat dissipated by a person by convection or by radiation can be calculated if the necessary data are available. During a recent investigation conducted by Dr. Yaglou at Harvard University with three male adults clothed in three-piece suits and at rest during the tests, it was found that comfort conditions were produced with the following three sets of temperatures: air 71 F and MRT 71 F; air 63 F and MRT 79 F; and air 59 F and MRT 85 F. Additional sets of temperatures similar to the three found experimentally by Dr. Yaglou could be calculated if one knew: (1) The area of the body surface exposed to convection currents. (2) The mean temperature of the exposed skin and clothing. (3) The film coefficient. (4) The area of the body available for radiation. (5) The radiation factor.

The two surface areas (Items 1 and 4) can be measured and may be assumed to be, on an average, 18 and 15 sq ft, respectively. The radiation factor may be assumed to be 0.156, as explained in June. This leaves two unknowns—the mean surface temperature and the film coefficient.

Determining Required Temperatures

If the mean temperature of the exposed skin and clothing is assumed to be 80 F and the corresponding film coefficient is 1 Btu per hr per sq ft per F temperature difference, the calculated heat losses for Dr. Yaglou's three sets of temperatures (71 F and 71 F, 63 F and 79 F, and 59 F and 85 F) will be, respectively, 291, 321 and 303 Btu per hr per person, according to the equations given on pp. 360 and 361 of the June HPAC. It seems that these calculated heat losses agree sufficiently well with each other so that a mean surface temperature of 80 F and a film coefficient of 1 Btu may be considered satisfactory for use in calculating comfort conditions for various combinations of air temperatures and mean radiant temperatures, for male adults clothed as were Dr.

Fig. 1—Heat loss or gain by convection for various air temperatures, in Btu per hr per person, according to the formula $Q = 18 \times 1\ (80 - t_a)$, where Q is Btu per hr per person, 18 sq ft is the area of the body exposed to convection air currents, 1 Btu per hr per sq ft per F temperature difference is the film coefficient, 80 F is the mean surface temperature of the body, and t_a is the temperature of the air in the room in degrees Fahrenheit

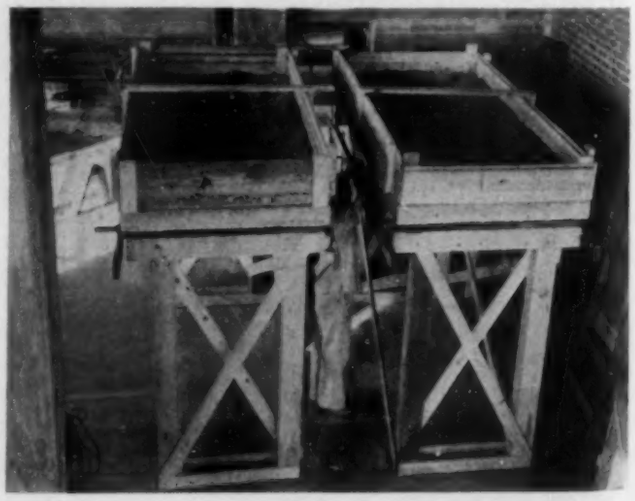
Fig. 2—Heat loss or gain by radiation for various mean radiant temperatures, in Btu per hr per person, according to the formula $Q = 15 \times 0.156\ [(540/100)^4 - (T_r/100)^4]$, where 15 sq ft is the area of the body available for radiation, 0.156 is the radiation factor for the body, 540 is the absolute mean surface temperature of body (460 + 80), T_r is the absolute mean radiant temperature of the room, and Q is amount of heat, Btu per hr per person

Fig. 3—Relationship between air temperature and mean radiant temperature for combined convection and radiation heat losses of 250, 300 or 350 Btu per hr per person, as indicated on curves

Yaglou's subjects. Naturally, comfort condition requirements vary with persons, with clothing and with states of rest and types of motion.

These data were used for the calculations for Figs. 1 and 2. These charts may be used as follows: If the air temperature is 60 F (Fig. 1), the heat loss by con-

Fig. 4—Laboratory test of heating pipe coil in concrete slab



vection will be about 350 Btu; the heat gain by radiation should therefore be about 50 Btu and, consequently, the mean radiant temperature (Fig. 2) should be about 83 F, in order that the net body heat loss may be about 300 Btu per hr. To facilitate finding corresponding air and radiant temperatures, Fig. 3 was constructed. It may be used as follows: If the mean radiant temperature in a room is 70 F, the corresponding air temperatures should be about 74, 71 or 68 F if the combined heat loss is to be about 250, 300 or 350 Btu per hr, respectively.

These values are for an adult male clothed in a three-piece suit and having a metabolic heat production rate of about 335, 400 or 465 Btu per hr, respectively. For different conditions and different persons, different combinations of air and radiant temperatures are necessary for comfort to result.

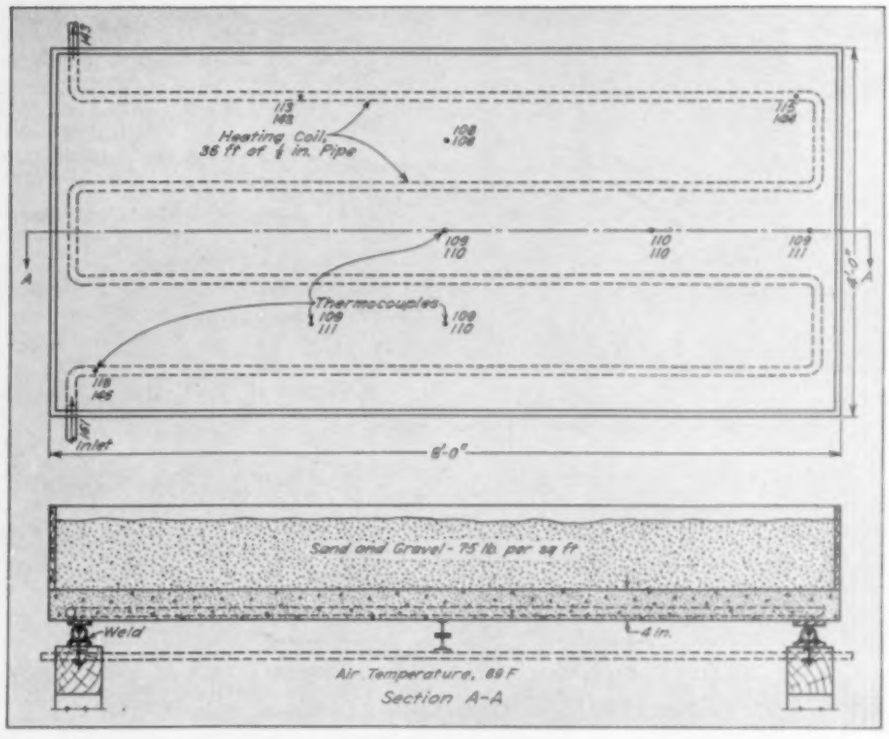


Fig. 5—Results of laboratory test of a pipe coil embedded in a concrete slab. The upper and lower figures show the temperatures in degrees Fahrenheit obtained at various locations for the upper and lower surfaces of the slab, respectively, with inlet and outlet water temperature values as indicated on the sketch

Figuring Building Heating Load

To determine the heating loads for a building equipped with radiant heating, one may proceed as for an ordinary heating system after having selected the desired indoor air temperature. The heat losses through the outside walls will be slightly higher for the same air temperatures than in the case of ordinary heating systems because the radiant energy emitted by the heating panels increases the temperature of the outside walls slightly. A good over-all check on heat loss calculation is that the total loss should be slightly lower than that for the ordinary heating system if the assumed indoor air temperature is slightly lower than the usual one.

Having determined the heat requirement of the several rooms in a building, the respective heating elements may be designed. Called heating panels, they consist generally of pipe coils placed in the ceiling, floor or walls, or suspended from the ceiling. The pipe coils are usually embedded in concrete slabs or covered with plaster.

Heat Dissipation from Coils in Slab

To determine the rate at which heat can be dissipated by a concrete slab in which heating coils are embedded and also the extent to which such heating coils can be used as reinforcement for the concrete slab, a series of tests was conducted at Texas A & M College, as shown in Fig. 4, and the results of one of these tests are given in Fig. 5. The concrete slab was reinforced only with the ½ in. pipe coil shown and was loaded with sand and gravel to 75 lb per sq ft. Nine thermocouples were attached to the upper surface of the slab and nine to the lower surface as shown by the dots in Fig. 5.

When water was flowing through the coil at the rate of 283 lb per hr, entering the coil at a temperature of 161 F and leaving at a temperature of 143 F and with, therefore, an average temperature of 152 F, the average temperature of the lower surface of the concrete slab was 144 F directly under the pipe coil, and 110 F midway between the coils. The average temperature of the upper surface of the slab was 115 F directly above the coil and 109 F midway between the coils, as shown by the temperature values lettered on Fig. 5.

Under these conditions, the concrete slab was dissipating heat at the rate of 10 Btu per hr per sq ft of external pipe coil surface, and per degree Fahrenheit temperature difference between the water in the pipe and the air beneath the slab. A considerable portion of the heat transferred from the pipe coil to the concrete slab was no doubt conducted into the bed of sand and gravel or emitted by the uninsulated edges of the slab. Consequently, the rate of heat transfer from the pipe coil to the slab found by experiment in this case is too high to be used in the design of panel warming systems.

When the heating coils are embedded in the concrete floor slab, a portion of the heat flows through the floor above the slab and the remainder flows through the ceiling below the slab. The division between these two quantities depends upon the degree of insulation of the slab above the coils. The quantity flowing upward generally varies from 5 to 30 per cent of the total heat dissipated by the pipe coil.

Methods of Installing Heating Coils

In the United States, it is customary to suspend the heating coils from the ceiling instead of embedding them in the concrete slab. By this method, the heating panel

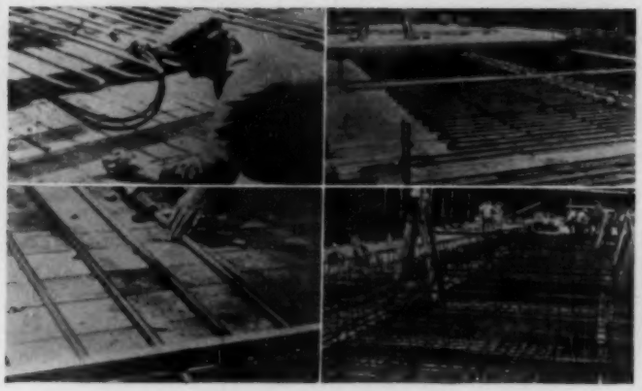


Fig. 6—Arrangement of pipe coils to be embedded in concrete slabs—European method

is constructed like the ordinary suspended ceiling, plastered on expanded metal and suspended from the floor construction, except that the heating coils rest directly on the expanded metal and are wired to it, and the plaster is applied so that the pipe coils are covered with it. An insulating layer is then placed over the heating coils and under the floor construction. The expanded metal serves the additional purpose of securing a uniform distribution of heat over the ceiling area.

The European method of placing heating coils in concrete slabs is shown in Fig. 6, and the American method of suspending the heating coils from the floor construction in Fig. 7.

[A third article by Dr. Giesecke will give additional design information. A previous article in the June HPAC discussed the fundamentals of radiant heating and cooling.]

Fig. 7—Arrangement of pipe coils to be enclosed in plaster and suspended from ceiling—American method

Important Task for Air Conditioning, Shepard Tells ASRE

Probably the most important task which faces the air conditioning industry today is to establish in the public mind (1) the need for air conditioning, and (2) the fact that the physical equipment is worth the price asked for it, John deB. Shepard* told members of the American Society of Refrigerating Engineers at their 27th spring meeting last month. Great strides have been made along this line in the past decade, he said, but the job is yet not done. In this connection he defined a luxury as a "comfort or a convenience with which we are not familiar," and a necessity as one with which we are well acquainted.

Another factor which is not fully appreciated is the relatively complex procedure necessary to apply air conditioning to any interior, he felt. The engineering involved in designing an automobile is probably more complex than that for an air conditioning system. However, in the case of an automobile, refrigerator, radio, etc., the engineering is done once and for all, and the final design may be reproduced many times and placed in use with the assurance it will perform satisfactorily against the well defined external conditions it will meet. In air conditioning, however, the engineer faces so many and varied external conditions that it is extremely difficult to do other than design to meet the specific requirements of each application. This fact has made necessary not only careful field engineering of each installation, but has forced air conditioning to be a contracting business. It will always remain a business in which a relatively large percentage of local labor and material will be necessary to the completion of most installations, he said.

Mr. Shepard believes that there is a need for advertised prices for air conditioning installations, that well paid year 'round salesmen are required and that more educational advertising will boost sales. He thinks year 'round functions of air conditioning are being more and more appreciated and the industry not only needs year 'round salesmen, but has a year 'round job for them to do.

E. R. Wolfert** presented a paper on the effect of superheat on compressor performance. In an investigation of cooling the motors for large, completely enclosed compressors for air conditioning, four methods were considered, one of which was suction gas refrigerant cooling by using the returning suction gas to pick up the heat generated by motor losses (patented). This method was the cause of the investigation, he reported, since picking up the motor losses by means of the suction gas results in increasing the superheat of this gas as it enters the compressor.

Mr. Wolfert concluded his paper by the following statements:

1) Increasing the superheat on the "Freon-12" compressors has a favorable effect on both capacity and overall efficiency on those machines tested.

2) The use of heat exchangers between liquid and suction lines in general increases the capacity and is probably the easiest and most economical means of increasing compressor capacity.

3) Since the suction gas temperature cannot easily be raised above 90 F by either air or heat exchangers between liquid and suction lines, motor losses or compressor losses can be used to increase suction gas temperatures without decreasing capacity or efficiency. This is especially important in self-contained and packaged units as air or water cooling devices can be eliminated by use of this principle.

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**Westinghouse Electric & Mfg. Co.

The Use of the Ring Joint on Oil and Steam Piping Service

F. R. Venton* and A. W. Marburg† Analyze Advantages of Ring Joints for the Flanged Connections on Steam and Oil Piping

SUMMARY

The ring joint—widely used as a fluid pressure seal for flanged joint connections—comprises a ring of either oval or octagonal cross section confined within tapered, straight sided grooves cut into the faces of the two flanges. As applied specifically to piping, it was conceived some 15 years ago in the Texas oil fields and has achieved a position as a joint of accepted merit where service conditions—on steam or oil piping—are severe. . . . . The authors give a mechanical analysis of the ring joint, discuss the effect of flange separation, and explain the advantages of the octagonal ring cross section. . . . . In conclusion, they point out that some trouble has been experienced in various steam power piping systems where oval rings were being used on high pressure service at elevated temperatures, and explain why the same trouble has not occurred in the oil industry. Realizing the existence of major differences between power plant and oil refinery operations, and the fact that fluctuating line temperature conditions were the greatest single cause for flanged joint leakage, an investigation of the characteristics of the ring joint, with special emphasis on its ability to withstand such fluctuations, was undertaken. Detailed discussion of the results of this investigation is to be given in a second article in the August issue of HPAC

THE ring joint is a widely used type of fluid pressure seal for flanged connections. This type of seal comprises a ring of either oval or octagonal cross section confined within tapered, straight sided grooves cut into the faces of the two flanges. This joint, as applied specifically to piping, was conceived some 15 years ago in the Texas oil fields, gradually found favor with an increasing number of designers and operators and finally achieved its present position as a joint of accepted merit where service conditions are severe.

The superior sealing quality of the ring joint with respect to the conventional flat gasket joint is satisfactorily explained by an analysis of the mechanics involved.

Mechanical Analysis of Ring Joint

The wedging effect of the ring in the commonly used 23 deg tapered grooves creates a compression in the ring cross section substantially in excess of the compression of a comparable flat gasket subjected to the same bolt load. The wedging action theory perhaps motivated the originators of the ring joint to use an oval ring fitted into straight sided grooves, whereby a theoretical line bearing would exist between the curved surfaces of the ring and the tangent groove sides. The extremely high unit bearing load around the line contact thus created was considered one of the chief advantages of the ring joint in spite of the attendant disadvantages to be discussed a little further on. An idea of the wedging compressions will be derived from the following equations for flat gaskets and ring joints.

In the case of a conventional flat gasket joint the theoretical unit compression n, which is here considered as being uniform over the entire compressed area A of the gasket, is expressed by:

Equation 1—

$$n = \frac{\text{Bolt Stress} \times \text{Total Bolt Area at Root of Threads}}{\text{Gasket Area}} = \frac{\text{Total Bolt Load}}{A} = \frac{P}{A}$$

For the 23 deg ring joint (Fig. 1) the total bolt load P must be balanced by the combined vertical components of the total loads N_1 and N_2 normal to the bearing surfaces plus the combined vertical components of the frictional resistances F_1 and F_2 tangential to the bearing surfaces. Therefore:

Equation 2—

$$P = (N_1 \sin\theta + F_1 \cos\theta) + (N_2 \sin\theta + F_2 \cos\theta)$$

where $\theta = 23$ deg;

$F_1 = \mu N_1$;

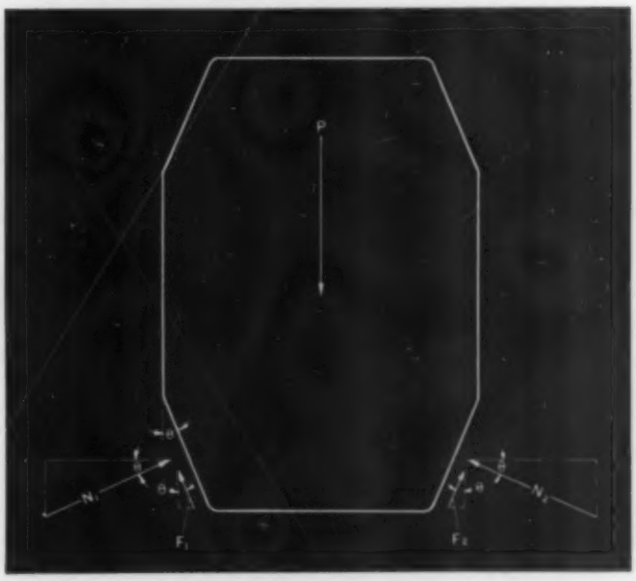
$F_2 = \mu N_2$;

μ = coefficient of static friction $\simeq 0.176$

$$P = N_1(\sin\theta + \mu\cos\theta) + N_2(\sin\theta + \mu\cos\theta)$$

$$N_1 + N_2 = \frac{P}{\sin\theta + \mu\cos\theta} = \text{total normal load on gasket bearing surfaces, lb}$$

Fig. 1—Forces acting on an octagonal ring assembled in a joint



*Technical Engineer, Research and Development Dept., Crane Co.
†Testing Engineer, Research and Development Dept., Crane Co.

Equation 3—

$$n = \frac{N_1 + N_2}{A} = \frac{P}{(\sin\theta + \mu\cos\theta)\,A} = \text{average normal load on gasket bearing surfaces, lb per sq in.}$$

$$(\sin\theta + \mu\cos\theta) = (0.39073 + 0.176 \times 0.92050) = 0.553$$

Since from Equation 3 the gasket area $A = P/n$ for a flat gasket joint and $A = P/0.553\,n$ for a 23 deg ring joint, it is apparent that for the same value of n (unit gasket compression) and under a given bolt load, the bearing surface of the ring type joint could be 1.8 times that of the corresponding flat gasket joint. This is a distinct advantage for the ring type joint, since a wider bearing surface is always favored except where it must be sacrificed in favor of increased unit loading. In the case of a relatively wide bearing surface the possibility of any irregularities traversing the entire width of the bearing, and thus providing a path for leakage, is more remote. The soundness of this reasoning is demonstrated by the popular acceptance of the plug type globe valve for use in lines where severe operating conditions are encountered.

The following sample calculations have been worked out in order to compare the normal gasket loadings resulting from a given bolt loading as applied to 6 in., 300 lb ASA small tongue and groove joints and octagonal section ring joints.

$A = 9.79$ sq in. for ring joint gasket.

$A = 6.09$ sq in. for small tongue and groove.

For the purpose of this example a bolt stress of 50,000 lb per sq in. has been assumed. The cross sectional area of a ¾ in. bolt at the root of the thread is 0.302 sq in., and since 12 such bolts are used in the 6 in., 300 lb joints, the total bolt area is 12×0.302 sq in. or 3.624 sq in. The total bolt load P is then $50{,}000 \times 3.624 = 181{,}000$ lb.

From Equation 3:

$$n = \frac{P}{0.553\,A} \text{ for ring joint gasket where } \theta = 23 \text{ deg.}$$

Substituting for all values, we find

$$n = \frac{181{,}000}{(0.553)\ (9.79)} = 33{,}500 \text{ lb per sq in. for ring joint gasket}$$

$$n = \frac{P}{A} \text{ for any flat gasket joint}$$

$$n = \frac{181{,}000}{6.09} = 29{,}800 \text{ lb per sq in. for small tongue and groove joint}$$

From the above calculations it is apparent that in spite of the larger bearing area of the octagonal ring, the normal loading is substantially higher than the normal loading of the small tongue and groove gasket.

Effect of Flange Separation

In the First Report of the Pipe Flanges Research Committee,[1] it is pointed out that flow between the adjoining faces of any pressure seal will cease only when, in the case of a gaseous medium, the spacing between the faces approaches mono-molecular dimensions. Since it is obvious that practical machining will yield no such optically true metal surfaces, it remains either for a relatively soft gasket or for extremely high compression to "iron out" the rough sealing faces. Note, however, that once the sealing faces are again separated, for any of a number of reasons, by so much as the thickness of a mono-molecular layer of the fluid, leakage will commence.

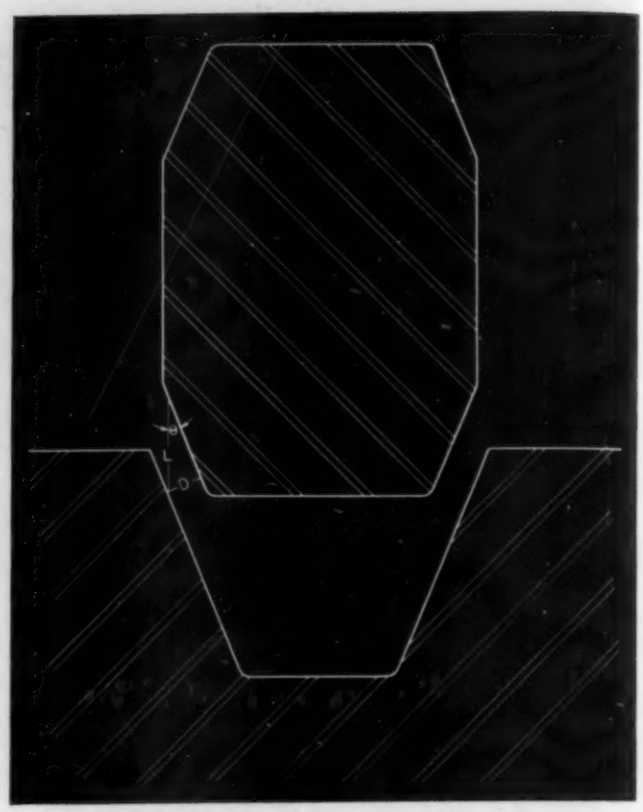


Fig. 2—Separation of bearing surfaces

In dealing with liquids the situation is shown to be altered by a consideration of surface tension, as Dr. H. J. Gough points out, and this condition is summed up by the expression:

$$d = \frac{2\,T\cos\theta}{p}$$

where L = axial flange separation, in.;
D = bearing surface separation resulting from L, in.;
d = special case of D at which leakage just occurs;
T = surface tension of liquid under consideration
= 72.8 dynes per centimeter or 0.000415 lb per in. for 68 F water;
θ = angle made at contact between joint face and meniscus = 110 deg if metal surface is greasy;
p = internal fluid pressure, lb per sq in.

For water under 1000 lb per sq in. internal pressure and at 68 F, the limiting distance between sealing faces becomes:

$$d = \frac{2\ (0.000415)\ (0.34202)}{1000} = 0.000000284 = 2.84 \times 10^{-7}$$

It is apparent that the allowable face separation is a very delicate dimension. The inclusion of the ring joint gasket between the sides of the grooves (46 deg total

[1]First Report of the Pipe Flanges Research Committee, prepared for the committee by Dr. H. J. Gough and published by the Institution of Mechanical Engineers, London, February, 1936.

included angle) serves as an aid to the ring joint in that unit separation of the flanges results in only fractional separation of the sealing faces of the gasket and grooves.

From Fig. 2, it is apparent that $D = L \sin \theta$, and since $\sin \theta = \sin 23$ deg, or 0.39073, $D = 0.39\ L$ for the 23 deg ring joint, whereas $D = L$ for flat gasket joints. This means that a given value of D, the normal separation of the ring joint bearing surfaces, will be created only by a vertical or axial flange separation L of 2.56 D. Consequently, the ring joint is capable of maintaining a pressure tight joint throughout a far greater range of axial flange displacement.

Since internal pressure and plastic deformation (creep), particularly at high temperatures, of the component bolts, nuts, flanges, and gaskets all conspire to increase the magnitude of L, the inclined sealing faces of the ring joint prove increasingly beneficial as temperatures increase.

Advantages of Octagonal Ring

While conducting a great number of hydrostatic pressure tests[2] on various ring joint assemblies in which rings of oval cross section were used, it was noted that in order to apply a given bolt tension it was necessary to go around the flange pulling up each bolt many more times than was the case with, for example, a corresponding joint of the flat gasket type. Upon dismantling such ring joint assemblies, it was found that the theoretical line bearing of the soft oval section rings had been deformed under the compressive load to provide flat bearing surfaces varying in width with the loadings applied. In effect, then, it was found that the oval section ring undergoes a permanent deformation of form upon being assembled into a flanged joint and the final condition of the deformed bearings easily suggests the ring of octagonal cross section. The difference in this respect between the rings of oval and octagonal cross section is that with the oval ring the inevitable flat tapered ring bearings are formed by dint of hard manual labor upon the part of the assembler, and the formed bearings are stressed to the yield point of the material, whereas on the octagonal section rings the forming of the bearing surfaces is easily and more perfectly achieved by a machining operation with the further advantage of a controlled normal loading on the ring bearing surfaces.

In addition to this very practical advantage of the octagonal section ring, it was established by hydrostatic tests that the octagonal section ring was at least the equal of the oval section ring when viewed in the light of their relative abilities to retain pressures. Since Mr. Petrie has already described[2] the hydrostatic tests conducted on both types of ring joints at some length, Table 1 will suffice as an illustration of their relative merits.

Oil and Steam Service Conditions

Ring joints have been used in increasing numbers by the oil industry for the past 10 or 15 years and have performed with satisfaction. In the past few years, however, several cases of trouble have developed in various steam power piping systems where oval section ring joints were being used on high pressure service at elevated temperatures.

[2]See The Ring Joint, by E. C. Petrie, HEATING, PIPING AND AIR CONDITIONING, April, 1937, pp. 213-220.

Table 1—Hydrostatic Tests on 12 In., 1350 Lb Flanged Joints

Bolt Stress Applied Lb per Sq In.	Initial Total Bolt Load Applied Lb	Leakage Pressure	
		Oval	Octagonal
21300	395300	1500	2500
30000	557400	1950	3200
45000	836100	3200	4200

This apparent contradiction is explained by an analysis of the service conditions prevalent in oil refinery and steam power plant installations. For example: A still used in refining oil, while usually operating at extremely high temperature (perhaps 1200 F), is rarely in continuous service for more than 30 to 90 days at a time, whereas a power plant is expected to operate without shutdown for a period of years. This discrepancy in time element is all important when the progressive creep of the component parts of a flanged joint is considered. The oil refineries, then, enjoy the benefits derived from short operating periods followed by a cleaning of the bearing surfaces and a re-stressing of the bolting. Also, the passage of hot oil vapors through a pipe line causes the interior of such a line to become coated with a coke, which fortunately effects an additional seal at all of the pipe joints in the line. This is true because the carbon deposit upon the bearing surfaces has the effect of increasing the interfacial tension between the metal and a liquid, thereby preventing wetting of the metal surface and inhibiting the flow of fluid across the faces. This is the same effect sought—unwittingly, in many cases—by automobile mechanics who will almost invariably grease a head gasket before installation. The grease on such a gasket is soon reduced under high temperatures to a carbon deposit on the gasket faces, which is helpful in maintaining pressure tight joints. Similarly, the light oil with which it is recommended that the ring joint gasket be coated before assembly provides for a carbon coating after the joint has been subjected to high temperature service. Experimental work is now being conducted to establish the relative merits of different coatings when applied to gaskets.

It was reasoned that under high temperature conditions and where parts were under stress for a matter of years, the creep of the soft steel oval section ring gasket was perhaps the limiting factor determining the life of such a joint. Since both ring material and design were apparently at fault, the soft iron because of its poor creep resistance under temperature, and the oval ring section because of its concentration of extreme bearing loads around a theoretical line contact, both were changed simultaneously. It has been our experience that the substitution of an SAE 1020 ring of octagonal cross section for the soft iron ring of oval cross section has remedied the difficulty.

Realizing the existence of the major differences between power plant and oil refinery operations, and realizing also the fact that fluctuating line temperature conditions were the greatest single cause for flanged joint leakage, an investigation of the characteristics of the ring joint has been undertaken with special emphasis upon its ability to withstand temperature fluctuations.

[A detailed discussion of the test data resulting from this investigation will be given in a second article.]

Water Treatment for Heating Boilers

By Kalman Steiner* and Ralph A. Nelson*

SUMMARY

It was established in a previous discussion of water treatment for heating boilers (published in the March, 1940, HPAC) that natural water supplies and even condensed steam or distilled water contain mineral matter that can seriously affect boiler operation. Chemical procedures for preventing scale formation, corrosion, embrittlement and priming fall into two classifications—internal and external treatment. The first comprises introduction of the chemicals directly into boiler water (or into the feed immediately before it enters the boiler) and the second involves causing the chemical and physical changes to take place before the water enters the boiler. . . . Methods of internal treatment of boiler water include use of soda ash, and numerous other chemicals such as sodium phosphate, sodium aluminate, and sodium silicate. The simplest form of external treatment is the open feedwater heater, the heating resulting in carbon dioxide and oxygen being driven partially from solution. A simple external chemical water treatment is the zeolite softener. . . . The lime-soda process has an advantage in that it actually reduces the amount of mineral taken into the boiler. . . . Other methods of control of effect of mineral matter within a boiler are the deconcentrator and continuous blowdown. . . . The carbonate-sulphate ratio is important in connection with preventing embrittlement

NATURAL water supplies contain mineral matter that can seriously affect boiler operation, and even condensed steam or distilled water can acquire properties inimical to proper and safe boiler operation.[1] The chemical procedures resorted to for preventing scale formation, corrosion, embrittlement and priming can be considered as falling into two classifications: internal treatment and external treatment. The first method involves introduction of chemicals directly into the boiler water, or into the feed immediately before it enters the boiler, so that subsequent chemical or physical changes occur within the boiler. The second method consists of conducting the chemical reactions and inducing the chemical and physical changes to occur before the water enters the boiler. Both methods have ramifications and complexities, but in general internal treatment is best suited to small plants and external treatment to large plants.

Temporary and Permanent Hardness

By *solubility* is meant the amount of a substance capable of dissolving in water. Most sodium salts are very soluble, and high concentrations of sodium compounds in water are possible. The salts of calcium and magnesium are much less soluble, and the concentrations of such compounds in water are much lower than with sodium salts. When a certain water has dissolved in it all the amount of a substance that it is capable of dissolving, it is said to be a saturated solution of the substance. Solubilities vary widely. For example, a saturated solution of sodium sulphate in water at 212 F has a concentration of 24,700 grains per gal, while at the same temperature a saturated solution of calcium carbonate has a concentration of but 1.16 grains per gal.

Calcium carbonate is ordinarily considered to be insoluble in water, but in the presence of carbon dioxide another compound is formed called calcium bicarbonate, $Ca(HCO_3)_2$, which is water soluble. The carbonate of magnesium is soluble, but in the presence of carbon dioxide, which is usually present in natural water supplies, it also forms the bicarbonate $Mg(HCO_3)_2$, which is even more soluble than the normal carbonate. Bicarbonates of calcium and magnesium are frequently referred to as the *temporary hardness* of water, for under the influence of heat the bicarbonates break down and carbon dioxide is expelled from the water, causing the residual normal carbonates to be thrown out of solution or precipitated because of their lower solubilities. Unless proper methods are utilized, this precipitated carbonate sludge forms boiler scale.

The other salts of calcium and magnesium (called *permanent hardness*), and for that matter the carbonates that still remain in solution after expulsion of the carbon dioxide, of course do not leave the boiler with the steam, but remain in solution until sufficient water has been evaporated to increase their concentrations to their saturation points. Then, since the water cannot hold further salts in solution beyond their respective saturation concentrations, the additional salts brought into the boiler by the feedwater separate from solution. These salts make additional precipitated sludge to settle on the boiler surface and form scale.

Scale resulting only from sulphate hardness sludge is usually a dense and hard formation. Scale from carbonate hardness only is inclined to be softer. When silica (sand) is also present in suspension in the feedwater, it tends when settling out to increase greatly the hardness of the scale deposit. Other factors influencing the type and nature of the scale in a boiler are the rate of boiler firing, arrangement of tubes with respect to radiant heat, and water circulation within the boiler.

*Ace Engineering Co.

[1] See Heating, Piping and Air Conditioning, March, 1940, pp. 177-179.

Soda Ash Treatment

A common type of internal treatment of boiler water is dosage with sodium carbonate (soda ash). When used as a boiler compound soda ash serves the following functions: Calcium and magnesium sulphates are converted into carbonates, the sodium being changed to the sulphate; calcium and magnesium bicarbonate are reduced to normal carbonate by action of the heat in driving off carbon dioxide; calcium carbonate being insoluble results in the removal of calcium hardness from the water. But the magnesium carbonate will remain in solution, so further action is necessary. Additional soda ash, over that which reacted with the sulphates, is required; this hydrolizes at high temperature to form sodium hydroxide, and magnesium carbonate promptly reacts with the hydroxide of sodium to form insoluble hydroxide of magnesium. The net result is that both sulphates and carbonates of calcium and magnesium are thrown out of solution by the combined action of heat and soda ash. Any acid present will of course be neutralized by the alkali.

When precipitates of calcium and magnesium are thus formed in the boiler, the sludge settles as a soft mud to the lower sections of the boiler, whence removal is accomplished by periodic blowdown of boiler water. Even though the blowdown be poorly regulated, the sludge—lacking sulphate precipitates—does not have bad scale forming qualities.

Other Boiler Compounds

Numerous other chemicals are used as boiler compound besides soda ash. Among them might be mentioned sodium phosphate (in three different forms, besides phosphoric acid itself), which precipitates calcium and magnesium as insoluble phosphates; sodium aluminate, which throws down insoluble calcium and magnesium aluminates; and sodium silicate, which forms insoluble calcium and magnesium silicates. As with precipitates from soda ash, blowdown is necessary for ultimate removal of the solids from the boiler water. Sodium aluminate, besides having softening qualities, also forms a heavy flocculent precipitate by reaction with alkali present, and this heavy floc helps considerably in coagulating the smaller particles of other insolubles and thereby assists in rapid settling of solids to the bottom of the boiler.

The action of caustic soda or sodium hydroxide is similar to that of soda ash, and it is sometimes used for internal treatment. It should be used with care, however, because of the danger that excess quantities will induce embrittlement of the boiler metal.

Commercially prepared and packaged boiler compounds usually employ two or more of the substances above mentioned.

Some natural water supplies are relatively free from troublesome impurities and comparatively simple treatment will keep scale from the boiler. But where water conditions are not so simple, it is always advisable that the treatment be recommended by some person or firm experienced in water chemistry. Further, periodic analysis and testing of the boiler water should be conducted, so that results of the treatment can be checked. Indiscriminate use of commercial compounds whose composition is not known is not to be recommended, for the results are then wholly a matter of chance.

Corrosion and Caustic Embrittlement

Corrosion of boilers is somewhat more complicated a subject than scaling. Most compounds are ineffective against severe corrosive conditions. Where such exist, it is best to retain the services of a chemist to supervise the water treatment. In larger plants the ordinary corrosive agents, CO_2 and oxygen, are eliminated from the feedwater. Some boiler compounds contain sodium sulphite, which has the function of absorbing oxygen.

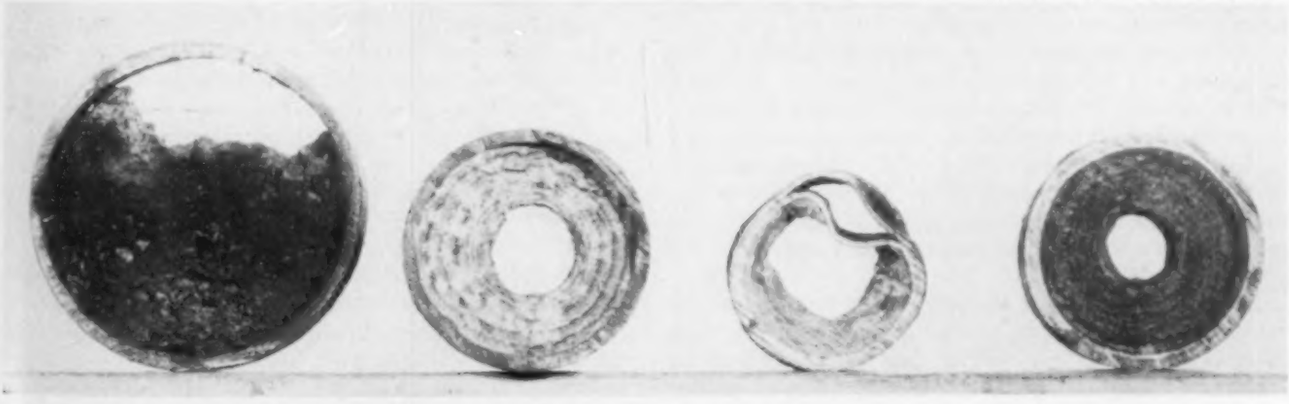
Caustic embrittlement prevention requires maintenance of the proper carbonate to sulphate ratio in the boiler water. Here again the services of a trained technician are valuable if the natural ratio is at great variance from the safe minimum. The soda ash present in many boiler compounds acts as an embrittlement inhibitor. Phosphates, tannates, and other substances included in some prepared boiler compounds, likewise have a retarding effect.

The Open Feedwater Heater

The simplest form of external treatment is the commonly used form of open feedwater heater. In this apparatus, condensate returns, fresh water make-up, and live steam all mingle together to make hot feed for the boiler. The tank in which this mixing occurs is vented to atmosphere to permit escape of such gases as are ex-

Specimens of feed lines and boiler tubes showing scale

Courtesy Dearborn Chemical Co.



pelled from the water. In this manner the heating resulting from the live steam causes carbon dioxide and oxygen to be partially driven from solution. The CO_2 of course has come from the breakdown of bicarbonates in the raw water make-up, so that the steam really serves the dual purpose of decomposing bicarbonates and expelling the resultant carbon dioxide. The oxygen introduced is from the fresh water also, being carried in solution in cold water. Originally intended merely to serve as a preheater for the feedwater, therefore, this heater also serves in part as a water treating device.

Were the hot feed permitted to remain quiescent for a sufficient length of time, the carbonate would settle out, or passing the feed through a filter would remove the precipitate. But usually the nature of the water feed system does not allow for settling time or filtration, so that any precipitate formed in the breakdown of temporary hardness is carried into the boiler, accompanied by such sediment as originally existed in the raw water, and of course the permanent hardness still in solution.

The Zeolite Softener

A simple external chemical water treatment is the zeolite water softener. A zeolite is a curious sort of insoluble sodium mineral substance that possesses the ability to effect a chemical exchange when in contact with water. In this exchange the metallic portions of the zeolite and dissolved salts in the water change places. By virtue of this remarkable exchange, calcium and magnesium are withdrawn from solution and an equivalent amount of sodium is added in their place. In other words, calcium bicarbonate is transformed into sodium bicarbonate, and so on with all the hardness, both temporary and permanent, of the water supply. After the zeolite has become exhausted of its available sodium, it is regenerated by backwashing with a strong brine solution, causing the calcium and magnesium to be in turn exchanged for a fresh sodium charge. This cycle of softening and regeneration can be repeated indefinitely.

Raw water supplies that contain high turbidity or suspended matter must be filtered before passing through the bed of zeolite to prevent fouling the zeolite mineral. Zeolite is not a suitable treatment for waters containing iron or manganese in solution; iron can be thrown out of solution by aeration which causes oxidation to insoluble iron oxide or hydroxide. Free mineral acids or dissolved CO_2 are objectionable in water for zeolite treatment because of their corrosive action upon the zeolite substance. Since zeolites are subject to disintegration at temperatures above 90 F, it follows that hot water cannot be zeolite softened.

Zeolites can be classified as natural and artificial, and as porous and non-porous. The decision as to which type to use, and whether to design a softener for a particular application as upflow or downflow, and the rate of flow of water through the softener, are all questions that can be answered only from a knowledge of the characteristics of the water involved. Here again the services of an experienced water chemist are almost indispensable.

Since the action of the zeolite is to increase the sodium salt content of the water, any water supply already high in such salts may be rendered unfit for boiler feed by zeolite softening. That is, the concentration of sodium salts may be made so high that objectionable priming and foaming within the boiler will result. This feature can be regulated to some extent by blowdown of boiler water.

The Lime-Soda Softener

The nature of the lime-soda softener is clearly indicated by its name. Water is treated with lime [calcium hydroxide, $Ca(OH)_2$] and soda ash prior to its use in the boiler as feed. Lime throws down temporary hardness and soda does likewise to the permanent hardness. The process may be conducted with the water cold, in which case at least four hours must be allowed for the precipitates to form and settle, and some alum (aluminum sulphate) must be added to assist in agglomerating the small particles of precipitates. Finally, the water is passed through a sand filter to remove whatever solids have not settled out in the tank. If the process is carried out with the water hot, settling time can be reduced to one hour.

The lime-soda process has the advantage that it actually reduces the amount of mineral taken into the boiler, and in most cases might be the preferred method. However, the investment required for equipment is not always justified in the majority of small boiler or heating plants.

Other Methods of Control

Various other schemes to control effect of mineral matter within the boiler are the deconcentrator and continuous blowdown, and combinations of them. The deconcentrator is a method for withdrawing a portion of the boiler water and removing from it the suspended matter either by settling or filtration or both. Continuous blowdown is employed to maintain concentration of dissolved solids in the boiler water below a predetermined maximum; the hot blowdown water is sometimes passed through a heat exchanger and utilized to preheat incoming feedwater. Sometimes continuous blowdown is used in conjunction with zeolite softening, where the high sodium content of the feed requires withdrawal of large amounts of boiler water to prevent high concentrations of sodium salts.

Carbonate-Sulphate Ratio

Mention has been made of the need to maintain a minimum carbonate-sulphate ratio in order to inhibit caustic embrittlement. The ASME recommends the following minimum ratios:

Boiler Pressure Lb per Sq In. Gage	Ratio Alkalinity/Sulphate
0 to 150	1/1
150 to 250	1/2
over 250	1/3

By the above ratios are meant the total concentration of carbonate in the boiler water divided by the total concentration of sulphate. When phosphate is used as boiler compound, then a concentration of 2.5 grains per gal of phosphate, in boilers operating under 250 lb gage, will inhibit embrittlement. When the carbonate-sulphate ratio is not within the safe limits above shown, chemical dosage must be utilized to maintain the safe balance.

The Psychrometric Chart
Its Application and Theory

By William Goodman*

SUMMARY

Publication of the text of this series on the psychrometric chart and its application and theory was completed in the April issue. Therefore, the appendices are now presented; these show the derivation of the various equations which have appeared in the text sections. Additional tables of end points for wet bulb lines for various barometric pressures are also given this month; some of these tables have been published previously and more are to appear later. . . . . The series of which this installment is a part has included new psychrometric charts for the low, medium and high temperature ranges, discussion of the theory underlying them, and instructions and supplemental data for solving problems in practice

PUBLICATION of the text of this series on the psychrometric chart was completed in April, and the first seven of the appendices showing how the equations given in the text are derived appeared in May and June. Publication of the appendices is continued this month.

Some of the tables of end points for wet bulb lines for various barometric pressures have already appeared and more of them are presented this month. Use of the values given in these tables was explained on p. 613 of the October, 1939, HPAC.

Appendix 8

Derivation of Equations used in Connections with the Discussions of Figs. 32 and 34

When drawing the lines of constant dry bulb temperature, the fact that the horizontal distance *2-3* of Fig. 32 (p. 239, April, 1940, HPAC) is proportional to the quantity $(0.24 + 0.45w)t$ is, as is apparent from the discussion in the text, of aid in drawing the lines of constant dry bulb temperature on the chart.

The proof of the facts illustrated in Fig. 32 is simple, but it is given here because of its value in illustrating the significant difference in the interpretation of the horizontal distances *1-2* and *2-3* of Fig. 32 when point *3* lies in the clear field and when it lies in the fogged field of the chart.

In Fig. 32, for clear air,

$$h = 0.24 + wh_g \quad \ldots\ldots [1]$$

But,
$$h_g = 1061 + 0.45t \quad \ldots\ldots [2]$$

Eliminating h_g between [1] and [2], and reassembling terms,

$$h = (0.24 + 0.45w)\,t + 1061w \quad \ldots\ldots [3]$$

For $t = 0$,
$$h = 1061w \quad \ldots\ldots [4]$$

Evidently, if point *3* lies in the clear air field of the chart, the horizontal distance *1-2*, between the lines of $h = 0$ and $t = 0$, is directly proportional to the value of the quantity $1061w$. Also, the horizontal distance *2-3* between the line of $t = 0$ and point *3* is directly proportional to the value of the quantity $(0.24 + 0.45w)\,t$ because from [3] above,

$$h - 1061w = (0.24 + 0.45w)t \quad \ldots\ldots [5]$$

The foregoing proof is valid only for a point in the clear air field of the chart. For points in the fogged field, the horizontal distances *1-2* and *2-3* are not proportional to the quantities shown in Fig. 32. Although this fact does not affect the utility of these relationships for drawing the lines of constant dry bulb temperature in the clear air field, this fact should be clearly understood to avoid the error of using these relationships for proofs involving points in the fogged field.

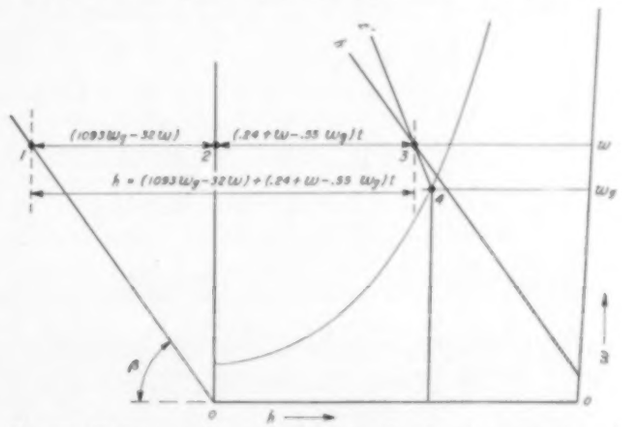


Fig. 35—Skeleton psychrometric chart showing interpretation of horizontal distances when state point lies in fogged field of chart

The quantities to which the horizontal distances are proportional when the air is fogged are illustrated in Fig. 35. These relationships are based on the fact that for any point such as *1* in the fogged air field of Fig. 35, the enthalpy of the free liquid suspended in the air must be included in determining the enthalpy of the fogged air.

Now the weight of saturated vapor mixed with the air is w_s as read at point *4* on the psychrometric chart of Fig. 35. In this figure points *3* and *4* both lie on the same line of wet bulb temperature. The weight of free liquid mixed with the air is $(w_3 - w_s)$.

The enthalpy at point *3* of Fig. 35 is greater than at point *4* by the heat of the free liquid suspended in the air. Hence,

$$h_3 = h_s + (w_3 - w_s)\,h_{f3} \quad \ldots\ldots [6]$$

Symbols Used

(For complete list, see p. 358, June, 1939, HPAC)

- h = enthalpy of air-vapor mixture, Btu per lb of dry air in the mixture
- h_f = enthalpy of moisture in liquid state, Btu per lb of water
- h_g = enthalpy of moisture in vapor state, Btu per lb of vapor
- t = dry bulb temperature, deg Fahr
- w = absolute humidity of the air-vapor mixture, lb of moisture per lb of dry air in the mixture
- w_s = weight of saturated vapor in fogged air, lb per lb of dry air

Subscript "1" refers to the initial state of the substance and subscript "2" refers to its final state.

*The Trane Co. Member of Board of Consulting and Contributing Editors.

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Table 10-End Points for Wet Bulb Lines
Barometric Pressure 29 in.

Wet Bulb Temp. t'	Dry Bulb Temperature, t				Absolute Humidity, w			
	For w=0		For w= 0.022	For w= 0.11	For t=40		For t= 120	For t= 450
	Over Ice	Over Water			Over Ice	Over Water		
1	2	3	4	5	6	7	8	9
-20	-18.17	-18.35						
-19	-17.08	-17.26						
-18	-15.98	-16.17						
-17	-14.87	-15.08						
-16	-13.76	-13.97						
-15	-12.64	-12.87						
-14	-11.52	-11.76						
-13	-10.39	-10.65						
-12	-9.26	-9.53						
-11	-8.12	-8.40						
-10	-6.97	-7.27						
-9	-5.82	-6.14						
-8	-4.66	-4.99						
-7	-3.49	-3.85						
-6	-2.32	-2.69						
-5	-1.13	-1.53						
-4	+0.06	-0.36						
-3	1.25	+0.82						
-2	2.46	2.00						
-1	3.68	3.20						
0	4.90	4.39						
1	6.14	5.60						
2	7.38	6.82						
3	8.64	8.04						
4	9.90	9.28						
5	11.18	10.53						
6	12.47	11.78						
7	13.77	13.05						
8	15.08	14.32						
9	16.41	15.62						
10	17.75	16.92						
11	19.11	18.23						
12	20.48	19.56						
13	21.86	20.89						
14	23.26	22.24						
15	24.68	23.61						
16	26.10	24.99						
17	27.55	26.38						
18	29.02	27.79						
19	30.51	29.22						
20	32.00	30.65						
21	33.54	32.12						
22	35.08	33.59						
23	36.64	35.09						
24	38.22	36.60						
25	39.82	38.12			0.0002872			
26	41.47	39.69			0.0006093	0.0002768		
27	43.11	41.25			0.0009391	0.0006302		
28	44.79	42.84			0.001274	0.0009894		
29	46.50	44.46						
30	48.23	46.10			0.001614	0.001354		
31	49.99	47.77			0.001961	0.001726		
32	51.77	49.45			0.002310	0.002100		
33		51.17				0.002486		
34		52.91				0.002876		
35		54.67				0.003272		
36		56.48				0.003677		
37		58.30				0.004088		
38		60.15				0.004506		
39		62.03				0.004931		
40		63.94				0.005364		
41		65.88						
42		67.86						
43		69.86						
44		71.90						
45		74.00						
46		76.12						
47		78.27						
48		80.47						
49		82.70						
50		84.99						
51		87.33						
52		89.67						
53		92.11						
54		94.55						
55		97.06						
56		99.63						
57		102.2						
58		104.9						
59		107.6						
60		110.4						
61		113.2						
62		116.1						
63		119.0						
64		122.0					0.0004516	

Wet Bulb Temp. t'	Dry Bulb Temperature, t				Absolute Humidity, w			
	For w=0		For w= 0.022	For w= 0.11	For t=40		For t= 120	For t= 450
	Over Ice	Over Water			Over Ice	Over Water		
1	2	3	4	5	6	7	8	9
65		125.2					0.001146	
66		128.3					0.001831	
67		131.5					0.002557	
68		134.8					0.003283	
69		138.1					0.004040	
70		141.6					0.004806	
71		145.0					0.005584	
72		148.7					0.006400	
73		152.3					0.007208	
74		156.1					0.008068	
75		159.9					0.008927	
76		163.8					0.009817	
77		167.9					0.01074	
78		172.0					0.01167	
79		176.1	79.92				0.01262	
80		180.5	84.15				0.01360	
81		184.9	88.47				0.01461	
82		189.4	92.90				0.01564	
83		194.0	97.41				0.01669	
84		198.7	102.0				0.01777	
85		203.5	106.8				0.01888	
86		208.5	111.6				0.02003	
87		213.6	116.6				0.02120	
88		218.8						
89		224.1						
90		229.6						
91		235.2						
92		240.9						
93		246.8						
94		252.8						
95		259.0						
96		265.3						
97		271.8						
98		278.5						
99		285.4						
100		292.3						
101		299.5						
102		306.9						
103		314.5						
104		322.3						
105		330.2						
106		338.4						
107		347.0						
108		355.6						
109		364.5						
110		373.6						
111		382.8						
112		392.5						
113		402.4						
114		412.6						
115		423.0						
116		433.8						
117		444.8						
118							0.001246	
119							0.003603	
120							0.006082	
121							0.008616	
122							0.01119	
123							0.01388	
124							0.01664	
125							0.01952	
126							0.02244	
127							0.02550	
128							0.02865	
129						135.7	0.03189	
130						149.4	0.03523	
131						163.7	0.03874	
132						177.7	0.04216	
133						190.8	0.04585	
134						208.5	0.04972	
135						224.2	0.05359	
136						240.6	0.05764	
137						257.7	0.06188	
138						275.5	0.06628	
139						293.2	0.07069	
140						311.6	0.07528	
141						330.7	0.08005	
142						350.9	0.08508	
143						371.3	0.09021	
144						392.5	0.09551	
145						414.3	0.1010	
146						437.5	0.1068	

Table 11-End Points for Wet Bulb Lines
Barometric Pressure 30 in.

Wet Bulb Temp. t'	Dry Bulb Temperature, t				Absolute Humidity, w			
	For w=0		For w= 0.022	For w= 0.11	For t=40		For t= 120	For t= 450
	Over Ice	Over Water			Over Ice	Over Water		
1	2	3	4	5	6	7	8	9
-20	-18.24	-18.40						
-19	-17.14	-17.32						
-18	-16.04	-16.23						
-17	-14.94	-15.14						
-16	-13.83	-14.04						
-15	-12.72	-12.94						
-14	-11.60	-11.84						
-13	-10.48	-10.73						
-12	-9.35	-9.61						
-11	-8.22	-8.49						
-10	-7.07	-7.36						
-9	-5.93	-6.23						
-8	-4.77	-5.09						
-7	-3.61	-3.95						
-6	-2.44	-2.80						
-5	-1.26	-1.64						
-4	-0.08	-0.48						
-3	+1.11	+0.69						
-2	2.31	1.87						
-1	3.52	3.06						
0	4.74	4.25						
1	5.97	5.45						
2	7.20	6.66						
3	8.45	7.88						
4	9.71	9.11						
5	10.98	10.34						
6	12.26	11.59						
7	13.54	12.85						
8	14.85	14.11						
9	16.17	15.40						
10	17.49	16.68						
11	18.84	17.99						
12	20.20	19.30						
13	21.56	20.62						
14	22.95	21.97						
15	24.35	23.32						
16	25.77	24.69						
17	27.20	26.07						
18	28.65	27.46						
19	30.12	28.87						
20	31.60	30.30						
21	33.12	31.75						
22	34.63	33.20						
23	36.18	34.68						
24	37.75	36.18						
25	39.33	37.68						
26	40.95	39.23			0.0001857			
27	42.57	40.77			0.0005039	0.0001714		
28	44.28	42.35			0.0008285	0.0005198		
29	45.91	43.94			0.001158	0.0008740		
30	47.68	45.56			0.001495	0.001234		
31	49.36	47.21			0.001837	0.001601		
32	51.11	48.86			0.002180	0.001971		
33		50.56				0.002351		
34		52.28				0.002735		
35		54.01				0.003124		
36		55.79				0.003523		
37		57.58				0.003928		
38		59.40				0.004339		
39		61.26				0.004757		
40		63.14				0.005183		
41		65.04						
42		66.99						
43		68.96						
44		70.96						
45		73.02						
46		75.10						
47		77.21						
48		79.37						
49		81.57						
50		83.81						
51		86.10						
52		88.39						
53		90.79						
54		93.18						
55		95.64						
56		98.15						
57		100.7						
58		103.3						
59		106.0						
60		108.7						
61		111.4						
62		114.3						
63		117.2						
64		120.1					0.0001690	

Wet Bulb Temp. t'	Dry Bulb Temperature, t				Absolute Humidity, w			
	For w=0		For w= 0.022	For w= 0.11	For t=40		For t= 120	For t= 450
	Over Ice	Over Water			Over Ice	Over Water		
1	2	3	4	5	6	7	8	9
65		123.1					0.0006868	
66		126.1					0.001362	
67		129.3					0.002068	
68		132.5					0.002775	
69		135.8					0.003511	
70		139.1					0.004257	
71		142.5					0.005025	
72		146.0					0.005812	
73		149.6					0.006610	
74		153.3					0.007440	
75		157.0					0.008280	
76		160.8					0.009139	
77		164.8					0.01004	
78		168.7					0.01094	
79		172.8					0.01186	
80		177.0	80.80				0.01281	
81		181.3	85.03				0.01380	
82		185.7	89.34				0.01480	
83		190.1	93.72				0.01583	
84		194.7	98.19				0.01687	
85		199.4	102.8				0.01795	
86		204.2	107.5				0.01906	
87		209.2	112.4				0.02020	
88		214.2	117.3				0.02136	
89		219.4						
90		224.7						
91		230.2						
92		235.7						
93		241.4						
94		247.2						
95		253.2						
96		259.3						
97		265.6						
98		272.1						
99		278.8						
100		285.5						
101		292.4						
102		299.6						
103		307.0						
104		314.5						
105		322.1						
106		330.1						
107		338.3						
108		346.6						
109		355.1						
110		364.0						
111		372.9						
112		382.2						
113		391.8						
114		401.5						
115		411.6						
116		422.0						
117		432.6						
118		443.5						
119								0.0009309
120								0.003313
121								0.005741
122								0.008216
123								0.01081
124								0.01345
125								0.01620
126								0.01903
127								0.02191
128								0.02497
129								0.02804
130						133.5		0.03129
131						147.2		0.03462
132						160.9		0.03796
133						175.2		0.04147
134						189.9		0.04508
135						205.3		0.04885
136						220.6		0.05264
137						237.0		0.05669
138						253.7		0.06094
139						271.1		0.06515
140						289.5		0.06948
141						306.9		0.07406
142						326.0		0.07884
143						345.5		0.08370
144						365.6		0.08873
145						386.4		0.09396
146						408.2		0.09944
147						430.6		0.1057

Substituting equation 3 of this appendix,

$$h_2 = (0.24 + 0.45w_2)\,t_2 + 1061w_2 + (w_2 - w_g)\,h_{fg} \quad \ldots\ldots\ldots\ldots [7]$$

Put $t_2 = t_s$ and $h_{fg} = t_2 - 32$. Also from Fig. 35, $w_g = w_s$

Hence,

$$h_2 = (0.24 + 0.45w_g)\,t_2 + 1061w_g + (w_2 - w_g)\quad (t_2 - 32) \ldots\ldots [8]$$

Clearing and reassembling terms,

$$h_2 = (0.24 + w_2 - 0.55w_g)\,t_2 + (1093w_g - 32w_2) \quad \ldots\ldots\ldots\ldots [9]$$

If $h_2 = h$ and $w_2 = w$ for any point in the fogged field of the chart,

$$h = (0.24 + w - 0.55w_g)\,t + (1093w_g - 32w) \quad \ldots\ldots\ldots\ldots [10]$$

If $t = 0$, $\quad h_2 = 1093w_g - 32w \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$

Hence, for points in the fogged field the horizontal distance *1-2* of Fig. 35, between the lines of $h = 0$ and $t = 0$, is not proportional to $(1061w)$, but to $(1093w_g - 32w)$. Also for this case, the horizontal distance *2-3* is proportional to $(0.24 + w - 0.55w_g)t$ as shown in Fig. 35. It is interesting to note that for clear air when $w_g = w$, equation 10 reduces to equation 3.

[*To be concluded*]

Contractors Hear Air Conditioning, Heating Committee Reports

Selling and installing of air conditioning is coming to be recognized as strictly a contractor's problem, the committee on air conditioning of the Heating, Piping and Air Conditioning Contractors National Association stated in its report presented at the association's 51st annual convention in New York City, and the period of pioneer or missionary selling of air conditioning is drawing to a close. The committee therefore strongly advised its members to become better acquainted with proper methods of pursuing the air conditioning business, which should not only be profitable but should also be decidedly helpful in their heating and piping business.

The report recommended that where consulting engineers write complete specifications and provide plans sufficiently in detail for intelligent bidding, such air conditioning installations are entirely within the province of the work of the association members. The report recommended that the members educate themselves on marketing, engineering, installation and servicing of installations, and that each provide an organization of the necessary technical assistance.

The recommendations advised members to refuse to accept responsibility of making good on performance guarantees unless the member has checked the plan and its specifications and ascertained from his own knowledge and experience that the equipment and installation on which he is estimating are adequate to perform the requirements of the guarantee.

In addition to these recommendations the report suggested—for consideration by all the industry—that contractors re-affirm the position of the association that the heating contractor is the logical final outlet for air conditioning machinery and apparatus and should be recognized as such; that he should be enabled to buy and quote on any make of apparatus or material he chooses, naming in his main bid the product upon which it is based and quoting alternates on other equipment; that contractors and manufacturers coöperate to obtain the adoption of safety codes which will produce adequate safety requirements with minimum installation expense; and that a conference be arranged for the study of rating capacities of apparatus and an agreement be reached as to the factor of safety to be applied to such ratings.

A report of the committee on boiler output called attention to the new IBR testing and rating code for cast iron heating boilers and said that it believed the work marked a big step in the advancement of radiator heating. The IBR net load recommendations are in most cases higher than previously published by the committee in its booklet Net Load Recommendations for Heating Boilers because of two things.

First, the IBR recommendations are based on coal having a heat value of 13,000 Btu, and previous recommendations were based on lower heat value coal. The IBR code takes care of this by publishing a table of conversion factors.

The other reason is that owing to lack of uniform test data, it was previously felt for the protection of the industry and the consumer that the published ratings should be on the conservative side. However, having the actual test data, which were reviewed by a committee of competent engineers, the committee said it was now in position to accept the manufacturers' recommendations with much more confidence.

The committee stated it has never been the desire of the association to require a consumer to purchase a boiler larger than his actual need, but to protect him against the possibility of purchasing one too small.

In the report of the committee on standards, it was stated that its aim is to assist in developing a code of reasonable safety requirements for comfort cooling which may be used as a model for cities and municipalities throughout the country. Members were urged to watch legislation which is either under way or proposed in their localities. The committee on standards is now working on the subject of refrigeration compressor rating, which work is very closely related to that of the committee on air conditioning and is similar to that of the committee on boiler output.

The report stated that some months ago the Milwaukee association suggested that manufacturers of convectors provide an air chamber or a tapping for an air chamber, and said that some manufacturers have such air chambers available for purchase and all of them are now providing such tappings. The committee also proposes to request the American Society of Heating and Ventilating Engineers to extend its convector testing code so that tests will be required with convector temperatures down to 120 F for hot water.

A number of other committee reports were presented to the membership, including that of the committee on welding which has compiled a set of procedures or specifications for metallic arc welding.

J. E. McNevin was elected president of the HPACCNA; Arthur F. Nass was named vice-president; S. Austin Pope, treasurer; and Joseph C. Fitts, secretary.

Keep the Piping Clean

A "Must" at Pinkham Medicine Co.

By Otis E. Russell* (with Francis A. Westbrook)

SUMMARY

Piping is "industry's greatest transportation system," plays an essential part in the manufacture of many products. At the Lydia E. Pinkham Medicine Co. plant, cleanliness is important for the product must be sterile as it is liable to fermentation, which might cause discoloration and deterioration on the druggists' shelves. . . . . Brass piping is used, and the piping maintenance schedule calls for cleaning the filling line every Friday with a soda ash solution, boiling rinse water, a chlorine solution and live steam. The other lines are cleaned in the same way after each batch, except for the chlorine

THE Lydia E. Pinkham Medicine Co., Lynn, Mass., uses brass piping for the transportation of liquid materials in the process of manufacture. At one time discoloration and deterioration of the medicine on druggists' shelves, due to lack of a sufficient degree of sterility, was a problem; but since the installation of the present system of piping and the development of piping maintenance methods this difficulty has been practically eliminated.

The first step in the manufacturing process is the making of a menstruum or solvent of licorice in a glass lined tank. This menstruum is pumped through brass piping to a 500 gal percolator. From the licorice tank part of the menstruum is pumped to the mixers to moisten the ground herbs. The herbs are dropped into the 500 gal percolator with the additional menstruum, the mixture remaining for 40 to 48 hr. It is circulated continuously during this period by a small rotary pump through small copper tubes on the outside, which carry the material from the bottom of the percolator and drop it in at the top. Copper tubing is used because it bends easily and is readily adjusted as desired.

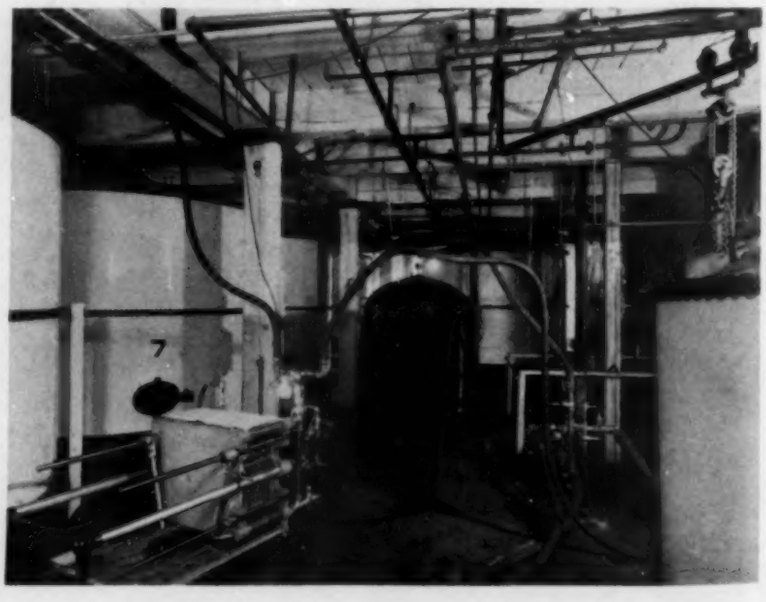
From the percolator the medicine flows by gravity through brass piping to receiving tanks on the floor below. It is drawn from these tanks, passed through the first pasteurizing operation and then runs to the storage tanks on the floor below.

The medicine is drawn from the top of the storage tanks by siphoning through rubber hose to a centrifugal pump, which delivers it to a 500 gal tank where it is mixed with asbestos wool. Another centrifugal pump takes the mixture of medicine and asbestos from the tank and delivers it to the first filter. From the filter the clarified medicine is forced by the filter pump pressure into receiving tanks. A second filtering is accomplished by means of a portable sheet filter having rubber hose connections for the sake of flexibility. The product is forced through this filter by a small centrifugal pump which also forces it into receiving tanks after passing through the filter. The vitamins are added at this point.

The medicine next runs by gravity to receiving tanks on the first floor. From these it is pumped by bronze centrifugal pumps through the second pasteurizer on the third floor and then on without stopping to glass lined tanks on the fourth floor where it is held for at least 30 min at the pasteurizing temperature of approximately 165 F. From here it descends to cooling coils on the third floor, from which it continues by gravity to the bottling machinery on the first floor.

From the second pasteurizer to the bottle filling machine, union couplings are used to avoid pockets which might retain anything which would make it difficult to keep the line clean. This is particularly necessary for this section of piping because there is no more pasteurizing or filtering and this is the final stage before bottling. All the rest of the pipe lines have regular brass fittings.

Much attention is given to keeping the piping clean. The section between the second pasteurizer and the filling line is cleaned every Friday by a soda ash solution, followed by boiling rinse water, a chlorine solution and finally live steam—to be sure that it is thoroughly sterilized. All the other pipe line sections are cleaned in the same way after the making of every batch of medicine, which comes to two or three times a week, except that the chlorine solution is omitted. Each cleaning step is continued for 20 to 30 min, the liquids being circulated by the pumps which are thus simultaneously cleaned.



View of the filter room, showing the storage tanks, sheet filter and (in the background) the various hose lines to and from the filters. Near the ceiling, adjacent to the elevator shaft, is the brass pipe line running from the first pasteurizer to the storage tanks. This is the line provided with couplings

*Superintendent, Lydia E. Pinkham Medicine Co.

Properties of Mixtures of Air and Saturated Water Vapor for Barometric Pressures from 22 In. to 32 In. of Mercury

By William Goodman*

Barometric Pressure 32 In. of Mercury

All tabulated values (except temperatures and pressures) are quantities per pound of dry air in the mixture.

Temp Deg Fahr	Absolute Humidity		Volume		Humid Specific Heat	1061w	Enthalpy (Heat Content)		Temp Deg Fahr	Absolute Humidity		Volume		Humid Specific Heat	1061w	Enthalpy (Heat Content)	
	Pounds	Grains	Dry Air Cu Ft	Volume Increase of Humid Air Per Cent			Water Vapor Btu	Air-Vapor Mixture Btu		Pounds	Grains	Dry Air Cu Ft	Volume Increase of Humid Air Per Cent			Water Vapor Btu	Air-Vapor Mixture Btu
t	w	w	v_D		s''		h_v	h	t	w	w	v_D		s''		h_v	h
1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
— 40	0.0001086	0.7603	9.89	0.01746	0.2401	0.1152	0.1133	—9.487	40	0.004857	34.00	11.78	0.7805	0.2422	5.153	5.242	14.84
— 39	.0001152	.8063	9.92	.01852	.2401	.1222	.1202	—9.240	41	.005050	35.35	11.80	.8116	.2423	5.358	5.452	15.29
— 38	.0001220	.8542	9.94	.01962	.2401	.1295	.1274	—8.993	42	.005251	36.76	11.82	.8437	.2424	5.571	5.672	15.75
— 37	.0001292	.9045	9.96	.02077	.2401	.1371	.1350	—8.745	43	.005458	38.20	11.85	.8771	.2425	5.790	5.897	16.22
— 36	.0001368	.9573	9.99	.02199	.2401	.1451	.1429	—8.497	44	.005672	39.71	11.87	.9117	.2426	6.018	6.132	16.69
— 35	0.0001446	1.012	10.01	0.02325	0.2401	0.1534	0.1512	—8.249	45	0.005898	41.28	11.90	0.9476	0.2427	6.257	6.378	17.18
— 34	.0001530	1.071	10.03	.02460	.2401	.1624	.1600	—8.000	46	.006128	42.90	11.92	0.9846	.2428	6.502	6.630	17.67
— 33	.0001618	1.133	10.06	.02601	.2401	.1716	.1693	—7.751	47	.006365	44.56	11.94	1.023	.2429	6.754	6.890	18.17
— 32	.0001711	1.198	10.08	.02751	.2401	.1815	.1791	—7.501	48	.006613	46.29	11.97	1.063	.2430	7.016	7.160	18.68
— 31	.0001807	1.265	10.10	.02905	.2401	.1917	.1892	—7.251	49	.006868	48.07	11.99	1.104	.2431	7.287	7.439	19.20
— 30	0.0001910	1.337	10.13	0.03071	0.2401	0.2027	0.2001	—7.000	50	0.007134	49.94	12.01	1.146	0.2432	7.569	7.731	19.73
— 29	.0002018	1.413	10.15	.03245	.2401	.2141	.2115	—6.749	51	.007409	51.87	12.04	1.190	.2433	7.861	8.032	20.27
— 28	.0002129	1.490	10.17	.03423	.2401	.2259	.2232	—6.497	52	.007688	53.82	12.06	1.236	.2435	8.157	8.338	20.82
— 27	.0002248	1.574	10.20	.03614	.2401	.2385	.2358	—6.244	53	.007985	55.89	12.08	1.283	.2436	8.472	8.663	21.38
— 26	.0002370	1.659	10.22	.03811	.2401	.2515	.2487	—5.991	54	.008284	57.99	12.11	1.331	.2437	8.789	8.991	21.95
— 25	0.0002501	1.751	10.25	0.04020	0.2401	0.2653	0.2625	—5.738	55	0.008595	60.17	12.13	1.381	0.2439	9.119	9.333	22.53
— 24	.0002639	1.847	10.27	.04242	.2401	.2800	.2771	—5.483	56	.008920	62.44	12.15	1.433	.2440	9.464	9.690	23.13
— 23	.0002783	1.948	10.29	.04474	.2401	.2952	.2924	—5.228	57	.009251	64.75	12.18	1.486	.2442	9.815	10.05	23.73
— 22	.0002933	2.053	10.32	.04715	.2401	.3112	.3083	—4.972	58	.009598	67.19	12.20	1.542	.2443	10.18	10.43	24.35
— 21	.0003088	2.162	10.34	.04965	.2401	.3277	.3248	—4.715	59	.009951	69.66	12.22	1.598	.2445	10.56	10.82	24.98
— 20	0.0003256	2.279	10.36	0.05234	0.2402	0.3454	0.3425	—4.458	60	0.01032	72.21	12.25	1.658	0.2446	10.94	11.22	25.62
— 19	.0003429	2.400	10.39	.05513	.2402	.3638	.3609	—4.199	61	.01070	74.87	12.27	1.719	.2448	11.35	11.64	26.28
— 18	.0003610	2.527	10.41	.05804	.2402	.3830	.3801	—3.940	62	.01109	77.66	12.30	1.782	.2450	11.77	12.08	26.96
— 17	.0003799	2.659	10.43	.06107	.2402	.4030	.4002	—3.680	63	.01150	80.50	12.32	1.847	.2452	12.20	12.53	27.65
— 16	.0003999	2.799	10.46	.06429	.2402	.4243	.4214	—3.419	64	.01191	83.38	12.34	1.914	.2454	12.64	12.98	28.34
— 15	0.0004205	2.944	10.48	0.06761	0.2402	0.4462	0.4434	—3.157	65	0.01235	86.46	12.37	1.983	0.2456	13.10	13.47	29.07
— 14	.0004423	3.096	10.50	.07111	.2402	.4693	.4665	—2.894	66	.01279	89.53	12.39	2.054	.2458	13.57	13.95	29.79
— 13	.0004653	3.257	10.53	.07481	.2402	.4937	.4910	—2.629	67	.01325	92.78	12.41	2.129	.2460	14.06	14.46	30.54
— 12	.0004892	3.425	10.55	.07865	.2402	.5191	.5164	—2.364	68	.01373	96.10	12.44	2.205	.2462	14.57	14.98	31.30
— 11	.0005138	3.596	10.58	.08260	.2402	.5451	.5426	—2.097	69	.01422	99.52	12.46	2.283	.2464	15.08	15.52	32.08
— 10	0.0005403	3.782	10.60	0.08686	0.2402	0.5732	0.5708	—1.829	70	0.01472	103.1	12.48	2.365	0.2466	15.62	16.08	32.88
— 9	.0005673	3.971	10.62	.09121	.2403	.6019	.5997	—1.560	71	.01524	106.7	12.51	2.448	.2469	16.17	16.66	33.70
— 8	.0005961	4.173	10.65	.09584	.2403	.6325	.6304	—1.290	72	.01579	110.5	12.53	2.535	.2471	16.75	17.26	34.54
— 7	.0006255	4.379	10.67	.1006	.2403	.6637	.6618	—1.018	73	.01634	114.4	12.55	2.625	.2474	17.34	17.87	35.39
— 6	.0006565	4.596	10.69	.1056	.2403	.6966	.6948	—0.7452	74	.01692	118.4	12.58	2.717	.2476	17.95	18.51	36.27
— 5	0.0006894	4.826	10.72	0.1108	0.2403	0.7315	0.7299	—0.4701	75	0.01751	122.5	12.60	2.811	0.2479	18.57	19.16	37.16
— 4	.0007231	5.062	10.74	.1163	.2403	.7673	.7660	—0.1941	76	.01812	126.8	12.63	2.909	.2482	19.22	19.83	38.07
— 3	.0007584	5.309	10.76	.1219	.2403	.8047	.8037	+0.0837	77	.01875	131.3	12.65	3.011	.2484	19.90	20.54	39.02
— 2	.0007956	5.569	10.79	.1279	.2404	.8441	.8434	0.3634	78	.01940	135.8	12.67	3.115	.2487	20.58	21.26	39.98
— 1	.0008346	5.842	10.81	.1342	.2404	.8855	.8852	0.6452	79	.02007	140.5	12.70	3.222	.2490	21.29	22.00	40.96
0	0.0008742	6.119	10.83	0.1405	0.2404	0.9275	0.9275	0.9275	80	0.02076	145.3	12.72	3.333	0.2493	22.02	22.76	41.96
1	.0009159	6.411	10.86	.1473	.2404	0.9717	0.9722	1.212	81	.02148	150.3	12.74	3.448	.2497	22.79	23.56	43.00
2	.0009593	6.717	10.88	.1543	.2404	1.018	1.019	1.499	82	.02221	155.5	12.77	3.565	.2500	23.56	24.37	44.05
3	.001005	7.036	10.91	.1616	.2405	1.067	1.068	1.788	83	.02297	160.8	12.79	3.687	.2503	24.37	25.22	45.14
4	.001053	7.373	10.93	.1694	.2405	1.118	1.119	2.079	84	.02374	166.2	12.81	3.811	.2507	25.19	26.08	46.24
5	0.001103	7.718	10.95	0.1773	0.2405	1.170	1.172	2.372	85	0.02455	171.8	12.84	3.941	0.2511	26.05	26.97	47.37
6	.001154	8.077	10.98	.1855	.2405	1.224	1.227	2.667	86	.02538	177.7	12.86	4.074	.2514	26.93	27.90	48.54
7	.001208	8.453	11.00	.1941	.2405	1.281	1.285	2.965	87	.02624	183.7	12.88	4.211	.2518	27.84	28.85	49.73
8	.001264	8.845	11.02	.2031	.2406	1.341	1.345	3.265	88	.02712	189.8	12.91	4.352	.2522	28.77	29.83	50.95
9	.001322	9.255	11.05	.2126	.2406	1.403	1.408	3.568	89	.02803	196.2	12.93	4.499	.2526	29.74	30.85	52.21
10	0.001382	9.676	11.07	0.2222	0.2406	1.467	1.473	3.873	90	0.02897	202.8	12.96	4.648	0.2530	30.74	31.89	53.49
11	.001447	10.13	11.09	.2326	.2407	1.535	1.542	4.182	91	.02994	209.6	12.98	4.804	.2535	31.76	32.97	54.81
12	.001512	10.59	11.12	.2431	.2407	1.604	1.613	4.493	92	.03093	216.5	13.00	4.963	.2539	32.81	34.07	56.15
13	.001579	11.05	11.14	.2539	.2407	1.675	1.685	4.805	93	.03196	223.7	13.03	5.128	.2544	33.91	35.22	57.54
14	.001652	11.56	11.16	.2656	.2407	1.753	1.763	5.123	94	.03302	231.1	13.05	5.297	.2549	35.03	36.41	58.97
15	0.001726	12.08	11.19	0.2775	0.2408	1.831	1.843	5.443	95	0.03410	238.7	13.07	5.471	0.2554	36.18	37.62	60.42
16	.001802	12.62	11.21	.2898	.2408	1.912	1.925	5.765	96	.03522	246.6	13.10	5.651	.2559	37.37	38.87	61.91
17	.001882	13.17	11.24	.3026	.2409	1.997	2.011	6.091	97	.03637	254.6	13.12	5.836	.2564	38.59	40.15	63.43
18	.001966	13.76	11.26	.3160	.2409	2.085	2.101	6.421	98	.03758	263.0	13.14	6.028	.2569	39.87	41.50	65.02
19	.002052	14.36	11.28	.3298	.2409	2.177	2.194	6.754	99	.03881	271.6	13.17	6.226	.2575	41.17	42.87	66.63
20	0.002142	14.99	11.31	0.3443	0.2410	2.272	2.292	7.092	100	0.04006	280.4	13.19	6.427	0.2580	42.51	44.28	68.28
21	.002236	15.65	11.33	.3594	.2410	2.372	2.393	7.433	101	.04137	289.6	13.21	6.636	.2586	43.89	45.74	69.98
22	.002332	16.32	11.35	.3748	.2411	2.474	2.497	7.777	102	.04272	299.0	13.24	6.851	.2592	45.32	47.25	71.73
23	.002431	17.02	11.38	.3909	.2411	2.580	2.605	8.125	103	.04411	308.8	13.26	7.072	.2599	46.80	48.81	73.53
24	.002537	17.76	11.40	.4079	.2411	2.692	2.719	8.479	104	.04553	318.7	13.29	7.302	.2605	48.31	50.40	75.36
25	0.002643	18.50	11.42	0.4249	0.2412	2.804	2.834	8.834	105	0.04700	329.0	13.31	7.537	0.2612	49.86	52.04	77.24
26	.002759	19.31	11.45	.4435	.2412	2.927	2.959	9.199	106	.04851	339.6	13.33	7.780	.2618	51.47	53.74	79.18
27	.002874	20.12	11.47	.4621	.2413	3.050	3.085	9.565	107	.05008	350.6	13.36	8.030	.2625	53.14	55.50	81.18
28	.002994	20.96	11.49	.4814	.2414	3.177	3.215	9.935	108	.05169	361.8	13.38	8.288	.2633	54.84	57.30	83.22
29	.003120	21.84	11.52	.5016	.2414	3.310	3.351	10.31	109	.05335	373.5	13.40	8.553	.2640	56.61	59.17	85.33
30	0.003251	22.76	11.54	0.5227	0.2415	3.450	3.493	10.69	110	0.05506	385.4	13.43	8.828	0.2648	58.42	61.09	87.49
31	.003389	23.72	11.57	.5448	.2415	3.595	3.643	11.08	111	.05681	397.7	13.45	9.109	.2656	60.28	63.06	89.70
32	.003525	24.68	11.59	.5666	.2416	3.740	3.792	11.47	112	.05863	410.4	13.47	9.400	.2664	62.21	65.10	91.98
33	.003673	25.71	11.61	.5904	.2417	3.898	3.953	11.87	113	.06051	423.6	13.50	9.699	.2672	64.20	67.21	94.33
34	.003825	26.77	11.64	.6148	.2417	4.058	4.118	12.28	114	.06244	437.1	13.52	10.01	.2681	66.25	69.38	96.74
35	0.003981	27.87	11.66	0.6400	0.2418	4.224	4.288	12.69	115	0.06443	451.0	13.54	10.32	0.2690	68.36	71.62	99.22
36	.004145	29.02	11.68	.6662	.2419	4.398	4.467	13.11	116	.06649	465.4	13.57	10.65	.2699	70.55	73.94	101.78
37	.004314	30.20	11.71	.6932	.2419	4.578	4.651	13.53	117	.06860	480.2	13.59	10.99	.2709	72.79	76.31	104.39
38	.004489	31.42	11.73	.7214	.2420	4.763	4.841	13.96	118	.07077	495.4	13.62	11.34	.2719	75.09	78.75	107.07
39	.004669	32.69	11.75	.7503	.2421	4.954	5.038	14.40	119	.07300	511.0	13.64	11.70	.2729	77.45	81.26	109.82

*The Trane Co. Member of Board of Consulting and Contributing Editors. Copyright, 1940, by William Goodman. next page.

(Tabulations for 22 in., 23 in., 24 in., 25 in., 26 in., 27 in., 28 in., 29 in., 30 in. and 31 in. were published in July, August, October, November and December, 1939, and March, April, May and June, 1940.)

Keep the Piping Clean

A "Must" at Pinkham Medicine Co.

By Otis E. Russell* (with Francis A. Westbrook)

SUMMARY

Piping is "industry's greatest transportation system," plays an essential part in the manufacture of many products. At the Lydia E. Pinkham Medicine Co. plant, cleanliness is important for the product must be sterile as it is liable to fermentation, which might cause discoloration and deterioration on the druggists' shelves. . . . . Brass piping is used, and the piping maintenance schedule calls for cleaning the filling line every Friday with a soda ash solution, boiling rinse water, a chlorine solution and live steam. The other lines are cleaned in the same way after each batch, except for the chlorine

THE Lydia E. Pinkham Medicine Co., Lynn, Mass., uses brass piping for the transportation of liquid materials in the process of manufacture. At one time discoloration and deterioration of the medicine on druggists' shelves, due to lack of a sufficient degree of sterility, was a problem; but since the installation of the present system of piping and the development of piping maintenance methods this difficulty has been practically eliminated.

The first step in the manufacturing process is the making of a menstruum or solvent of licorice in a glass lined tank. This menstruum is pumped through brass piping to a 500 gal percolator. From the licorice tank part of the menstruum is pumped to the mixers to moisten the ground herbs. The herbs are dropped into the 500 gal percolator with the additional menstruum, the mixture remaining for 40 to 48 hr. It is circulated continuously during this period by a small rotary pump through small copper tubes on the outside, which carry the material from the bottom of the percolator and drop it in at the top. Copper tubing is used because it bends easily and is readily adjusted as desired.

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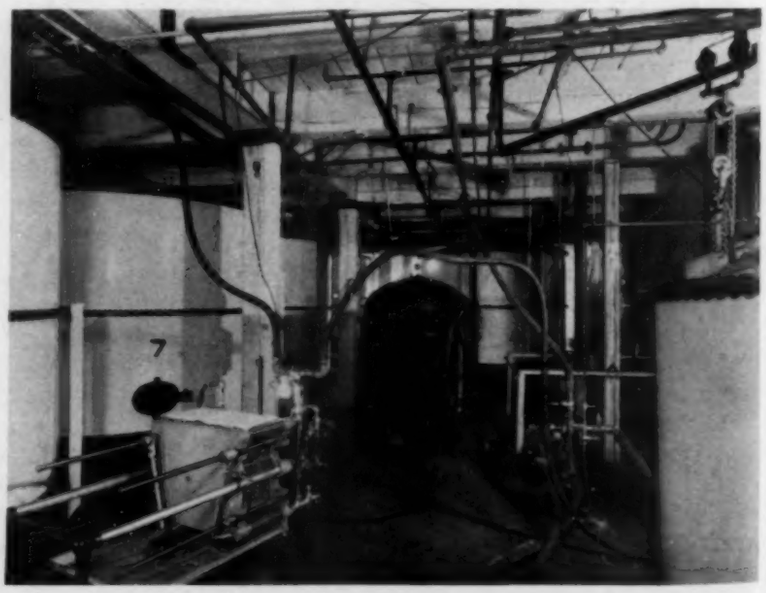
The medicine is drawn from the top of the storage tanks by siphoning through rubber hose to a centrifugal pump, which delivers it to a 500 gal tank where it is mixed with asbestos wool. Another centrifugal pump takes the mixture of medicine and asbestos from the tank and delivers it to the first filter. From the filter the clarified medicine is forced by the filter pump pressure into receiving tanks. A second filtering is accomplished by means of a portable sheet filter having rubber hose connections for the sake of flexibility. The product is forced through this filter by a small centrifugal pump which also forces it into receiving tanks after passing through the filter. The vitamins are added at this point.

The medicine next runs by gravity to receiving tanks on the first floor. From these it is pumped by bronze centrifugal pumps through the second pasteurizer on the third floor and then on without stopping to glass lined tanks on the fourth floor where it is held for at least 30 min at the pasteurizing temperature of approximately 165 F. From here it descends to cooling coils on the third floor, from which it continues by gravity to the bottling machinery on the first floor.

From the second pasteurizer to the bottle filling machine, union couplings are used to avoid pockets which might retain anything which would make it difficult to keep the line clean. This is particularly necessary for this section of piping because there is no more pasteurizing or filtering and this is the final stage before bottling. All the rest of the pipe lines have regular brass fittings.

Much attention is given to keeping the piping clean. The section between the second pasteurizer and the filling line is cleaned every Friday by a soda ash solution, followed by boiling rinse water, a chlorine solution and finally live steam—to be sure that it is thoroughly sterilized. All the other pipe line sections are cleaned in the same way after the making of every batch of medicine, which comes to two or three times a week, except that the chlorine solution is omitted. Each cleaning step is continued for 20 to 30 min, the liquids being circulated by the pumps which are thus simultaneously cleaned.



View of the filter room, showing the storage tanks, sheet filter and (in the background) the various hose lines to and from the filters. Near the ceiling, adjacent to the elevator shaft, is the brass pipe line running from the first pasteurizer to the storage tanks. This is the line provided with couplings

*Superintendent, Lydia E. Pinkham Medicine Co.

Properties of Mixtures of Air and Saturated Water Vapor for Barometric Pressures from 22 In. to 32 In. of Mercury

By William Goodman*

Barometric Pressure 32 In. of Mercury

All tabulated values (except temperatures and pressures) are quantities per pound of dry air in the mixture.

Temp Deg Fahr	Absolute Humidity		Volume				Enthalpy (Heat Content)		Temp Deg Fahr	Absolute Humidity		Volume				Enthalpy (Heat Content)	
	Pounds	Grains	Dry Air Cu Ft	Volume Increase of Humid Air Per Cent	Humid Specific Heat	1061w	Water Vapor Btu	Air-Vapor Mixture Btu		Pounds	Grains	Dry Air Cu Ft	Volume Increase of Humid Air Per Cent	Humid Specific Heat	1061w	Water Vapor Btu	Air-Vapor Mixture Btu
t	w	w	v_D		s''		h_v	h	t	w	w	v_D		s''		h_v	h
1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
— 40	0.0001086	0.7603	9.89	0.01746	0.2401	0.1152	0.1133	—9.487	40	0.004857	34.00	11.78	0.7805	0.2422	5.153	5.242	14.84
— 39	.0001152	.8063	9.92	.01852	.2401	.1222	.1202	—9.240	41	.005050	35.35	11.80	.8116	.2423	5.358	5.452	15.29
— 38	.0001220	.8542	9.94	.01962	.2401	.1295	.1274	—8.993	42	.005251	36.76	11.82	.8437	.2424	5.571	5.672	15.75
— 37	.0001292	.9045	9.96	.02077	.2401	.1371	.1350	—8.745	43	.005458	38.20	11.85	.8771	.2425	5.790	5.897	16.22
— 36	.0001368	.9573	9.99	.02199	.2401	.1451	.1429	—8.497	44	.005672	39.71	11.87	.9117	.2426	6.018	6.132	16.69
— 35	0.0001446	1.012	10.01	0.02325	0.2401	0.1534	0.1512	—8.249	45	0.005898	41.28	11.90	0.9476	0.2427	6.257	6.378	17.18
— 34	.0001530	1.071	10.03	.02460	.2401	.1624	.1600	—8.000	46	.006128	42.90	11.92	0.9846	.2428	6.502	6.630	17.67
— 33	.0001618	1.133	10.06	.02601	.2401	.1716	.1693	—7.751	47	.006365	44.56	11.94	1.023	.2429	6.754	6.890	18.17
— 32	.0001711	1.198	10.08	.02751	.2401	.1815	.1791	—7.501	48	.006613	46.29	11.97	1.063	.2430	7.016	7.160	18.68
— 31	.0001807	1.265	10.10	.02905	.2401	.1917	.1892	—7.251	49	.006868	48.07	11.99	1.104	.2431	7.287	7.439	19.20
— 30	0.0001910	1.337	10.13	0.03071	0.2401	0.2027	0.2001	—7.000	50	0.007134	49.94	12.01	1.146	0.2432	7.569	7.731	19.73
— 29	.0002018	1.413	10.15	.03245	.2401	.2141	.2115	—6.749	51	.007409	51.87	12.04	1.190	.2433	7.861	8.032	20.27
— 28	.0002129	1.490	10.17	.03423	.2401	.2259	.2232	—6.497	52	.007688	53.82	12.06	1.236	.2435	8.157	8.338	20.82
— 27	.0002248	1.574	10.20	.03614	.2401	.2385	.2358	—6.244	53	.007985	55.89	12.08	1.283	.2436	8.472	8.663	21.38
— 26	.0002370	1.659	10.22	.03811	.2401	.2515	.2487	—5.991	54	.008284	57.99	12.11	1.331	.2437	8.789	8.991	21.95
— 25	0.0002501	1.751	10.25	0.04020	0.2401	0.2653	0.2625	—5.738	55	0.008595	60.17	12.13	1.381	0.2439	9.119	9.333	22.53
— 24	.0002639	1.847	10.27	.04242	.2401	.2800	.2771	—5.483	56	.008920	62.44	12.15	1.433	.2440	9.464	9.690	23.13
— 23	.0002783	1.948	10.29	.04474	.2401	.2952	.2924	—5.228	57	.009251	64.75	12.18	1.486	.2442	9.815	10.05	23.73
— 22	.0002933	2.053	10.32	.04715	.2401	.3112	.3083	—4.972	58	.009598	67.19	12.20	1.542	.2443	10.18	10.43	24.35
— 21	.0003088	2.162	10.34	.04965	.2401	.3277	.3248	—4.715	59	.009951	69.66	12.22	1.598	.2445	10.56	10.82	24.98
— 20	0.0003256	2.279	10.36	0.05234	0.2402	0.3454	0.3425	—4.458	60	0.01032	72.21	12.25	1.658	0.2446	10.94	11.22	25.62
— 19	.0003429	2.400	10.39	.05513	.2402	.3638	.3609	—4.199	61	.01070	74.87	12.27	1.719	.2448	11.35	11.64	26.28
— 18	.0003610	2.527	10.41	.05804	.2402	.3830	.3801	—3.940	62	.01109	77.66	12.30	1.782	.2450	11.77	12.08	26.96
— 17	.0003799	2.659	10.43	.06107	.2402	.4030	.4002	—3.680	63	.01150	80.50	12.32	1.847	.2452	12.20	12.53	27.65
— 16	.0003999	2.799	10.46	.06429	.2402	.4243	.4214	—3.419	64	.01191	83.38	12.34	1.914	.2454	12.64	12.98	28.34
— 15	0.0004205	2.944	10.48	0.06761	0.2402	0.4462	0.4434	—3.157	65	0.01235	86.46	12.37	1.983	0.2456	13.10	13.47	29.07
— 14	.0004423	3.096	10.50	.07111	.2402	.4693	.4665	—2.894	66	.01279	89.53	12.39	2.054	.2458	13.57	13.95	29.79
— 13	.0004653	3.257	10.53	.07481	.2402	.4937	.4910	—2.629	67	.01325	92.78	12.41	2.129	.2460	14.06	14.46	30.54
— 12	.0004892	3.425	10.55	.07865	.2402	.5191	.5164	—2.364	68	.01373	96.10	12.44	2.205	.2462	14.57	14.98	31.30
— 11	.0005138	3.596	10.58	.08260	.2402	.5451	.5426	—2.097	69	.01422	99.52	12.46	2.283	.2464	15.08	15.52	32.08
— 10	0.0005403	3.782	10.60	0.08686	0.2402	0.5732	0.5708	—1.829	70	0.01472	103.1	12.48	2.365	0.2466	15.62	16.08	32.88
— 9	.0005673	3.971	10.62	.09121	.2403	.6019	.5997	—1.560	71	.01524	106.7	12.51	2.448	.2469	16.17	16.66	33.70
— 8	.0005961	4.173	10.65	.09584	.2403	.6325	.6304	—1.290	72	.01579	110.5	12.53	2.535	.2471	16.75	17.26	34.54
— 7	.0006255	4.379	10.67	.1006	.2403	.6637	.6618	—1.018	73	.01634	114.4	12.55	2.625	.2474	17.34	17.87	35.39
— 6	.0006563	4.596	10.69	.1056	.2403	.6966	.6948	—0.7452	74	.01692	118.4	12.58	2.717	.2476	17.95	18.51	36.27
— 5	0.0006894	4.826	10.72	0.1108	0.2403	0.7315	0.7299	—0.4701	75	0.01751	122.5	12.60	2.811	0.2479	18.57	19.16	37.16
— 4	.0007231	5.062	10.74	.1163	.2403	.7673	.7660	—0.1941	76	.01812	126.8	12.63	2.909	.2482	19.22	19.83	38.07
— 3	.0007584	5.309	10.76	.1219	.2403	.8047	.8037	+0.0837	77	.01875	131.3	12.65	3.011	.2484	19.90	20.54	39.02
— 2	.0007956	5.569	10.79	.1279	.2404	.8441	.8434	0.3634	78	.01940	135.8	12.67	3.115	.2487	20.58	21.26	39.98
— 1	.0008346	5.842	10.81	.1342	.2404	.8855	.8852	0.6452	79	.02007	140.5	12.70	3.222	.2490	21.29	22.00	40.96
0	0.0008742	6.119	10.83	0.1405	0.2404	0.9275	0.9275	0.9275	80	0.02076	145.3	12.72	3.333	0.2493	22.02	22.76	41.96
1	.0009159	6.411	10.86	.1473	.2404	0.9717	0.9722	1.212	81	.02148	150.3	12.74	3.448	.2497	22.79	23.56	43.00
2	.0009595	6.717	10.88	.1543	.2404	1.018	1.019	1.499	82	.02221	155.5	12.77	3.565	.2500	23.56	24.37	44.05
3	.001005	7.036	10.91	.1616	.2405	1.067	1.068	1.788	83	.02297	160.8	12.79	3.687	.2503	24.37	25.22	45.14
4	.001053	7.373	10.93	.1694	.2405	1.118	1.119	2.079	84	.02374	166.2	12.81	3.811	.2507	25.19	26.08	46.24
5	0.001103	7.718	10.95	0.1773	0.2405	1.170	1.172	2.372	85	0.02455	171.8	12.84	3.941	0.2511	26.05	26.97	47.37
6	.001154	8.077	10.98	.1855	.2405	1.224	1.227	2.667	86	.02538	177.7	12.86	4.074	.2514	26.93	27.90	48.54
7	.001208	8.453	11.00	.1941	.2405	1.281	1.285	2.965	87	.02624	183.7	12.88	4.211	.2518	27.84	28.85	49.73
8	.001264	8.845	11.02	.2031	.2406	1.341	1.345	3.265	88	.02712	189.8	12.91	4.352	.2522	28.77	29.83	50.95
9	.001322	9.255	11.05	.2126	.2406	1.403	1.408	3.568	89	.02803	196.2	12.93	4.499	.2526	29.74	30.85	52.21
10	0.001382	9.676	11.07	0.2222	0.2406	1.467	1.473	3.873	90	0.02897	202.8	12.96	4.648	0.2530	30.74	31.89	53.49
11	.001447	10.13	11.09	.2326	.2407	1.535	1.542	4.182	91	.02994	209.6	12.98	4.804	.2535	31.76	32.97	54.81
12	.001512	10.59	11.12	.2431	.2407	1.604	1.613	4.493	92	.03093	216.5	13.00	4.963	.2539	32.81	34.07	56.15
13	.001579	11.05	11.14	.2539	.2407	1.675	1.685	4.805	93	.03196	223.7	13.03	5.128	.2544	33.91	35.22	57.54
14	.001652	11.56	11.16	.2656	.2407	1.753	1.763	5.123	94	.03302	231.1	13.05	5.297	.2549	35.03	36.41	58.97
15	0.001726	12.08	11.19	0.2775	0.2408	1.831	1.843	5.443	95	0.03410	238.7	13.07	5.471	0.2554	36.18	37.62	60.42
16	.001802	12.62	11.21	.2898	.2408	1.912	1.925	5.765	96	.03522	246.6	13.10	5.651	.2559	37.37	38.87	61.91
17	.001882	13.17	11.24	.3026	.2409	1.997	2.011	6.091	97	.03637	254.6	13.12	5.836	.2564	38.59	40.15	63.43
18	.001966	13.76	11.26	.3160	.2409	2.085	2.101	6.421	98	.03758	263.0	13.14	6.028	.2569	39.87	41.50	65.02
19	.002052	14.36	11.28	.3298	.2409	2.177	2.194	6.754	99	.03881	271.6	13.17	6.226	.2575	41.17	42.87	66.63
20	0.002142	14.99	11.31	0.3443	0.2410	2.272	2.292	7.092	100	0.04006	280.4	13.19	6.427	0.2580	42.51	44.28	68.28
21	.002236	15.65	11.33	.3594	.2410	2.372	2.393	7.433	101	.04137	289.6	13.21	6.636	.2586	43.89	45.74	69.98
22	.002332	16.32	11.35	.3748	.2411	2.474	2.497	7.777	102	.04272	299.0	13.24	6.851	.2592	45.32	47.25	71.73
23	.002431	17.02	11.38	.3909	.2411	2.580	2.605	8.125	103	.04411	308.8	13.26	7.072	.2599	46.80	48.81	73.53
24	.002537	17.76	11.40	.4079	.2411	2.692	2.719	8.479	104	.04553	318.7	13.29	7.302	.2605	48.31	50.40	75.36
25	0.002643	18.50	11.42	0.4249	0.2412	2.804	2.834	8.834	105	0.04700	329.0	13.31	7.537	0.2612	49.86	52.04	77.24
26	.002759	19.31	11.45	.4435	.2412	2.927	2.959	9.199	106	.04851	339.6	13.33	7.780	.2618	51.47	53.74	79.18
27	.002874	20.12	11.47	.4621	.2413	3.050	3.085	9.565	107	.05008	350.6	13.36	8.030	.2625	53.14	55.50	81.18
28	.002994	20.96	11.49	.4814	.2414	3.177	3.215	9.935	108	.05169	361.8	13.38	8.288	.2633	54.84	57.30	83.22
29	.003120	21.84	11.52	.5016	.2414	3.310	3.351	10.31	109	.05335	373.5	13.40	8.553	.2640	56.61	59.17	85.33
30	0.003251	22.76	11.54	0.5227	0.2415	3.450	3.493	10.69	110	0.05506	385.4	13.43	8.828	0.2648	58.42	61.09	87.49
31	.003389	23.72	11.57	.5448	.2415	3.595	3.643	11.08	111	.05681	397.7	13.45	9.109	.2656	60.28	63.06	89.70
32	.003525	24.68	11.59	.5666	.2416	3.740	3.792	11.47	112	.05863	410.4	13.47	9.400	.2664	62.21	65.10	91.98
33	.003673	25.71	11.61	.5904	.2417	3.898	3.953	11.87	113	.06051	423.6	13.50	9.699	.2672	64.20	67.21	94.33
34	.003825	26.77	11.64	.6148	.2417	4.058	4.118	12.28	114	.06244	437.1	13.52	10.01	.2681	66.25	69.38	96.74
35	0.003981	27.87	11.66	0.6400	0.2418	4.224	4.288	12.69	115	0.06443	451.0	13.54	10.32	0.2690	68.36	71.62	99.22
36	.004145	29.02	11.68	.6662	.2419	4.398	4.467	13.11	116	.06649	465.4	13.57	10.65	.2699	70.55	73.94	101.78
37	.004314	30.20	11.71	.6932	.2419	4.578	4.651	13.53	117	.06860	480.2	13.59	10.99	.2709	72.79	76.31	104.39
38	.004489	31.42	11.73	.7214	.2420	4.763	4.841	13.96	118	.07077	495.4	13.62	11.34	.2719	75.09	78.75	107.07
39	.004669	32.69	11.75	.7503	.2421	4.954	5.038	14.40	119	.07300	511.0	13.64	11.70	.2729	77.45	81.26	109.82

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(Tabulations for 22 in., 23 in., 24 in., 25 in., 26 in., 27 in., 28 in., 29 in., 30 in. and 31 in. were published in July, August, September, October, November and December, 1939, and March, April, May and June, 1940.)

Properties of Mixtures of Air and Saturated Water Vapor—(Continued)
Barometric Pressure 32 In. of Mercury
All tabulated values (except temperatures and pressures) are quantities per pound of dry air in the mixture.

Temp Deg Fahr	Absolute Humidity		Volume		Humid Specific Heat	1061w	Enthalpy (Heat Content)	
	Pounds	Grains	Dry Air Cu Ft	Volume Increase of Humid Air Per Cent			Water Vapor Btu	Air-Vapor Mixture Btu
t	w	w	v_D		s''		h_v	h
1	2	3	4	5	6	7	8	9
120	0.07532	527.3	13.66	12.07	0.2739	79.92	83.89	112.69
121	.07772	544.0	13.69	12.43	.2750	82.46	86.59	115.63
122	.08015	561.0	13.71	12.84	.2761	85.04	89.32	118.60
123	.08270	578.9	13.73	13.25	.2772	87.75	92.20	121.72
124	.08531	597.2	13.76	13.67	.2784	90.51	93.15	124.91
125	0.08802	616.1	13.78	14.10	0.2796	93.39	98.21	128.21
126	.09080	635.6	13.80	14.54	.2809	96.34	101.36	131.60
127	.09369	655.8	13.83	15.00	.2822	99.40	104.61	135.09
128	.09665	676.5	13.85	15.48	.2835	102.54	107.96	138.68
129	.09971	697.9	13.87	15.97	.2849	105.79	111.41	142.37
130	0.1029	720.4	13.90	16.47	0.2863	109.20	115.05	146.25
131	.1062	743.3	13.92	16.99	.2878	112.66	118.74	150.18
132	.1095	766.3	13.95	17.53	.2893	116.15	122.46	154.14
133	.1130	790.8	13.97	18.08	.2908	119.86	126.43	158.35
134	.1166	816.1	13.99	18.66	.2925	123.69	130.51	162.67
135	0.1203	841.8	14.02	19.25	0.2941	127.60	134.68	167.08
136	.1241	868.6	14.04	19.86	.2958	131.66	139.02	171.66
137	.1281	896.5	14.06	20.49	.2976	135.88	143.54	176.42
138	.1322	925.5	14.09	21.15	.2995	140.27	148.23	181.35
139	.1364	954.9	14.11	21.82	.3014	144.73	153.00	186.36
140	0.1408	985.4	14.13	22.52	0.3034	149.36	157.94	191.54
141	.1453	1016.8	14.16	23.24	.3054	154.11	163.03	196.87
142	.1500	1050.1	14.18	23.98	.3075	159.17	168.44	202.52
143	.1548	1083.4	14.20	24.76	.3097	164.21	173.84	208.16
144	.1598	1118.3	14.23	25.55	.3119	169.51	179.51	214.07
145	0.1649	1154.6	14.25	26.38	0.3142	175.00	185.41	220.21
146	.1704	1192.7	14.28	27.24	.3167	180.77	191.59	226.63
147	.1760	1231.7	14.30	28.12	.3192	186.69	197.94	233.22
148	.1817	1272.0	14.32	29.04	.3218	192.80	204.49	240.01
149	.1877	1313.6	14.35	29.99	.3244	199.10	211.24	247.00
150	0.1939	1357.3	14.37	30.98	0.3273	205.73	218.35	254.35
151	.2003	1402.2	14.39	32.01	.3301	212.54	225.66	261.90
152	.2068	1447.3	14.42	33.06	.3330	219.37	233.00	269.48
153	.2139	1497.4	14.44	34.17	.3363	226.96	241.14	277.86
154	.2211	1547.6	14.46	35.31	.3395	234.58	249.32	286.28
155	0.2286	1600.1	14.49	36.51	0.3429	242.53	257.87	295.07
156	.2363	1654.3	14.51	37.74	.3464	250.75	266.72	304.16
157	.2442	1709.7	14.53	39.01	.3499	259.14	275.75	313.43
158	.2527	1769.2	14.56	40.35	.3537	268.16	285.45	323.37
159	.2615	1830.2	14.58	41.74	.3577	277.40	295.39	333.55
160	0.2705	1893.8	14.61	43.19	0.3617	287.04	305.76	344.16
161	.2800	1960.0	14.63	44.69	.3660	297.08	316.57	355.21
162	.2899	2029.2	14.65	46.26	.3705	307.57	327.87	366.75
163	.3002	2101.1	14.68	47.89	.3751	318.46	339.59	378.71
164	.3109	2176.3	14.70	49.61	.3799	329.86	351.88	391.24
165	0.3221	2254.7	14.72	51.39	0.3850	341.75	364.68	404.28
166	.3339	2337.1	14.75	53.26	.3902	354.24	378.14	417.98
167	.3461	2422.6	14.77	55.20	.3957	367.20	392.12	432.20
168	.3590	2512.9	14.79	57.24	.4016	380.89	406.88	447.20
169	.3724	2606.6	14.82	59.37	.4076	395.08	422.19	462.75
170	0.3865	2705.2	14.84	61.61	0.4139	410.03	438.32	479.12
171	.4012	2808.4	14.86	63.95	.4205	425.67	455.20	496.24
172	.4167	2917.2	14.89	66.42	.4275	442.16	473.00	514.28
173	.4331	3031.7	14.91	69.02	.4349	459.52	491.74	533.26
174	.4503	3152.0	14.94	71.75	.4426	477.75	511.43	553.19
175	0.4682	3277.3	14.96	74.48	0.4507	496.74	531.95	573.95
176	.4872	3410.4	14.98	77.60	.4592	516.92	553.75	595.99
177	.5073	3550.8	15.01	80.80	.4683	538.20	576.76	619.24
178	.5284	3698.8	15.03	84.15	.4778	560.63	601.00	643.72
179	.5508	3855.9	15.05	87.71	.4879	584.44	626.69	669.65
180	0.5748	4023.4	15.08	91.51	0.4987	609.83	654.15	697.35
181	.5999	4199.3	15.10	95.50	.5100	636.53	683.02	726.46
182	.6269	4388.3	15.12	99.76	.5221	665.14	713.98	757.66
183	.6556	4589.3	15.15	104.3	.5350	695.61	746.95	790.87
184	.6861	4802.5	15.17	109.1	.5487	727.92	781.91	826.07
185	0.7187	5030.8	15.19	114.3	0.5634	762.52	819.37	863.77
186	.7533	5273.0	15.22	119.8	.5790	799.24	859.13	903.77
187	.7905	5533.4	15.24	125.7	.5957	838.70	901.86	946.74
188	.8307	5815.2	15.27	132.1	.6138	881.42	948.12	993.24
189	.8743	6120.2	15.29	139.0	.6334	927.64	998.20	1043.6
190	0.9209	6446.6	15.31	146.4	0.6544	977.12	1051.7	1097.3
191	0.9716	6801.3	15.34	154.4	.6772	1030.9	1110.0	1155.8
192	1.027	7188.3	15.36	162.2	.7021	1089.5	1173.5	1219.6
193	1.088	7613.9	15.38	172.8	.7295	1154.0	1243.5	1289.8
194	1.153	8073.1	15.41	183.2	.7590	1223.7	1318.9	1365.5
195	1.226	8580.6	15.43	194.7	0.7916	1300.6	1402.3	1449.1
196	1.306	9142.0	15.45	207.4	.8277	1385.7	1494.6	1541.6
197	1.396	9770.6	15.48	221.6	.8681	1480.9	1597.8	1645.1
198	1.495	10,468	15.50	237.4	.9129	1586.6	1712.4	1759.9
199	1.586	11,104	15.52	251.8	.9538	1683.1	1817.1	1864.9
200	1.733	12,132	15.55	275.0	1.020	1838.9	1986.1	2034.1

Electric Heat Maintains Free Flow of Asphalt

By J. Schneider*

Electric heat makes asphalt run more freely through 600 ft of unloading pipe draining tank cars into two stills at the Byerlite Corp. plant, Cleveland, Ohio. Heating units wound spirally around the 2½ in. pipe maintain a free flowing temperature of about 400 F.

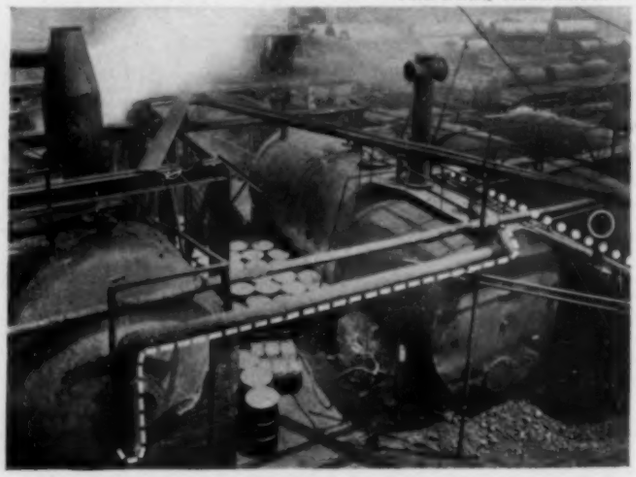
One of the advantages of the high temperature electric heat in this application is that it eliminates possibility of moisture in the asphalt. Any moisture in the unloading line would instantly flash into steam upon reaching the stills operating at about 500 F. This would cause the stills to bubble over, clog the exhaust condensers, and perhaps throw asphalt out of the top of the vent stacks.

The heating units used are spiralled in approximately 2½ ft spirals along the 600 ft of pipe. A sheet metal covering gives a uniform temperature to the line and eliminates hot spots, and, finally, there is an ample covering of heat insulating material. Thermostats control the heaters automatically, and series-parallel connection of the heating elements provides flexibility.

This installation has helped the Byerlite Corp. to reduce its unloading time, reduce unloading costs by 80 per cent (down to about 75c per tank car) and triple output.

This electrically heated unloading pipe line has helped the Byerlite Corp. to reduce time and cost of unloading asphalt tank cars and triple production

Photo courtesy General Electric Co.



*Cleveland Electric Illuminating Co.

Heating · Piping and Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

★ CONTENTS ★

JULY, 1940

Effect of Room Dimensions on the Performance of Direct Radiators and Convectors, by A. P. Kratz, M. K. Fahnestock, E. L. Broderick and S. Sachs..... 439

Methods of Rating the Noise from Air Conditioning Equipment, by J. S. Parkinson.. 447

Summer Cooling Load as Affected by Heat Gain Through Dry, Sprinkled and Water Covered Roofs, by F. C. Houghten, H. T. Olson and Carl Gutberlet..... 451

Transverse Heat Conductivity of Wood, by Frederick F. Wangaard..... 459

Local Chapter Reports..... 464

Candidates for Membership..... 465

Candidates Elected 466

BULLETIN BOARD

SUMMER MEETING WELL ATTENDED

Washington furnished unusual weather (fair and cool) for the Semi-Annual Meeting of the Society, which was attended by 350 members, guests and ladies, who had a most enjoyable three days visit to the Capitol (full details in the August issue).

• •

PREPARE FOR

The Fall Meeting of the Society to be held October 14-15 at Houston, Tex., under the auspices of the South Texas Chapter and with the North Texas Chapter members cooperating.

• • •

NEXT JANUARY

The 47th Annual Meeting is to be held at the Hotel Muehlebach, Kansas City, Mo., January 27 to 29, 1941, with Kansas City as the host Chapter.

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Effect of Room Dimensions on the Performance of Direct Radiators and Convectors

By A. P. Kratz,* M. K. Fahnestock,** E. L. Broderick,*** (*MEMBERS*), and S. Sachs†
Urbana, Ill.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and conducted at the Engineering Experiment Station, University of Illinois.

THE results of previous investigations [1,2,3,4,5] on the performance of direct steam radiators and convectors in test rooms 9 ft x 11 ft with 9 ft ceilings, in many cases showed rather large differences between the temperature of the air near the ceiling and that near the floor. The magnitudes of these differences, led to some question as to whether the results obtained in the comparatively small rooms were entirely characteristic of the performance of certain types of radiators and convectors, and whether somewhat different results might be obtained in rooms more nearly conforming in size with rooms commonly in use. The subsequent rebuilding of the room heating testing plant, and the installation of a test room 15 ft x 18 ft with an 8 ft-6 in. ceiling, afforded the opportunity to study the effect of the size of the room on the temperature gradients from floor to ceiling produced by direct steam radiators and convectors, and to determine whether conclusions with respect to the comparative performance of the different types of units were in any way affected by the size of the room.

Description of Apparatus

A complete description of the room heating testing plant involving two small test rooms 9 ft x 11 ft x 9 ft has been given in previous publications.[6] The test rooms were of standard frame construction, each room presenting two exposed walls. Means were provided for obtaining any desired temperatures below the floors and above the ceilings. In many respects the remodeled room heating testing plant shown in Figs. 1 and 2, was similar to the original plant, with the exception that it contained only one test room which was 15 ft wide, 18 ft long and had an 8 ft-6 in. ceiling. The test room was completely enclosed by a larger structure having walls, floor, and ceiling of 6 in. and 8 in. cork, which formed corridors on three sides of the room and included spaces corresponding to an attic and basement. As shown in Fig. 2, the walls enclosing the attic and basement spaces were insulated and equipped with cold storage doors, and the spaces were provided with electric heaters, affording means of controlling the temperatures above the ceiling and below the floor of the test room. Refrigerating coils, shown in Fig. 1, were placed in the north corridor and shielded from the north wall of the test room by means of a baffle or radiation shield. The west corridor was equipped with cold storage doors so that it could be isolated from the other corridors. This corridor was also provided with electric heaters for controlling the air temperature, and the arrangement made it possible to operate the test room with either two or three walls exposed to any desired temperature maintained in the cold room. The walls of the test room were constructed of bevel siding, building paper, sheathing, 3⅝ in. studs, and plasterboard. The north wall contained two 3 ft x 4 ft-6 in. double-hung windows, and the east and west walls each contained a similar window and a 3 ft x 7 ft paneled wood door with a 27½ in. x 36 in. glass in the upper portion. For the purpose of these tests the radiators and convectors were located at the north wall 2½ in. from the plaster and centrally in the space between the two windows. The cold storage doors at the end of the west corridor were closed and the test room was operated with only two walls exposed. Air movement over the north wall was obtained by means of fans.

The radiators and convectors were connected with a single pipe for steam and return condensation. The condensation was collected in a receiver located in the basement of the laboratory below the test plant, and was weighed in a tank on platform scales. A steam separator and an electric superheater installed in the line to the radiator or convector insured the use of dry steam.

The plant was completely equipped with thermocouples and temperature recorders in order to permit

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**Research Associate Professor, Engineering Experiment Station, University of Illinois.
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†Research Assistant, Engineering Experiment Station, University of Illinois.

[1]University of Illinois Engineering Experiment Station Bulletins Nos. 192 and 223.

[2]Investigation of Heating Rooms with Direct Steam Radiators Equipped with Enclosures and Shields, by A. C. Willard, A. P. Kratz, M. K. Fahnestock, and S. Konzo. (ASHVE TRANSACTIONS, Vol. 35, 1929, p. 77.)

[3]ASHVE RESEARCH REPORT No. 905—Steam Condensation an Inverse Index of Heating Effect, by A. P. Kratz, and M. K. Fahnestock. (ASHVE TRANSACTIONS, Vol. 37, 1931, p. 475.)

[4]ASHVE RESEARCH REPORT No. 927—Performance of Convectors, by A. P. Kratz and M. K. Fahnestock. (ASHVE TRANSACTIONS, Vol. 38, 1932, p. 351.)

[5]ASHVE RESEARCH REPORT No. 962—The Application of the Eupatheoscope for Measuring the Performance of Direct Radiators and Convectors in Terms of Equivalent Temperature, by A. C. Willard, A. P. Kratz, and M. K. Fahnestock. (ASHVE TRANSACTIONS, Vol. 39, 1933, p. 303.)

[6]Loc. cit. Notes 1-5.

Presented at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Washington, D. C., June, 1940.

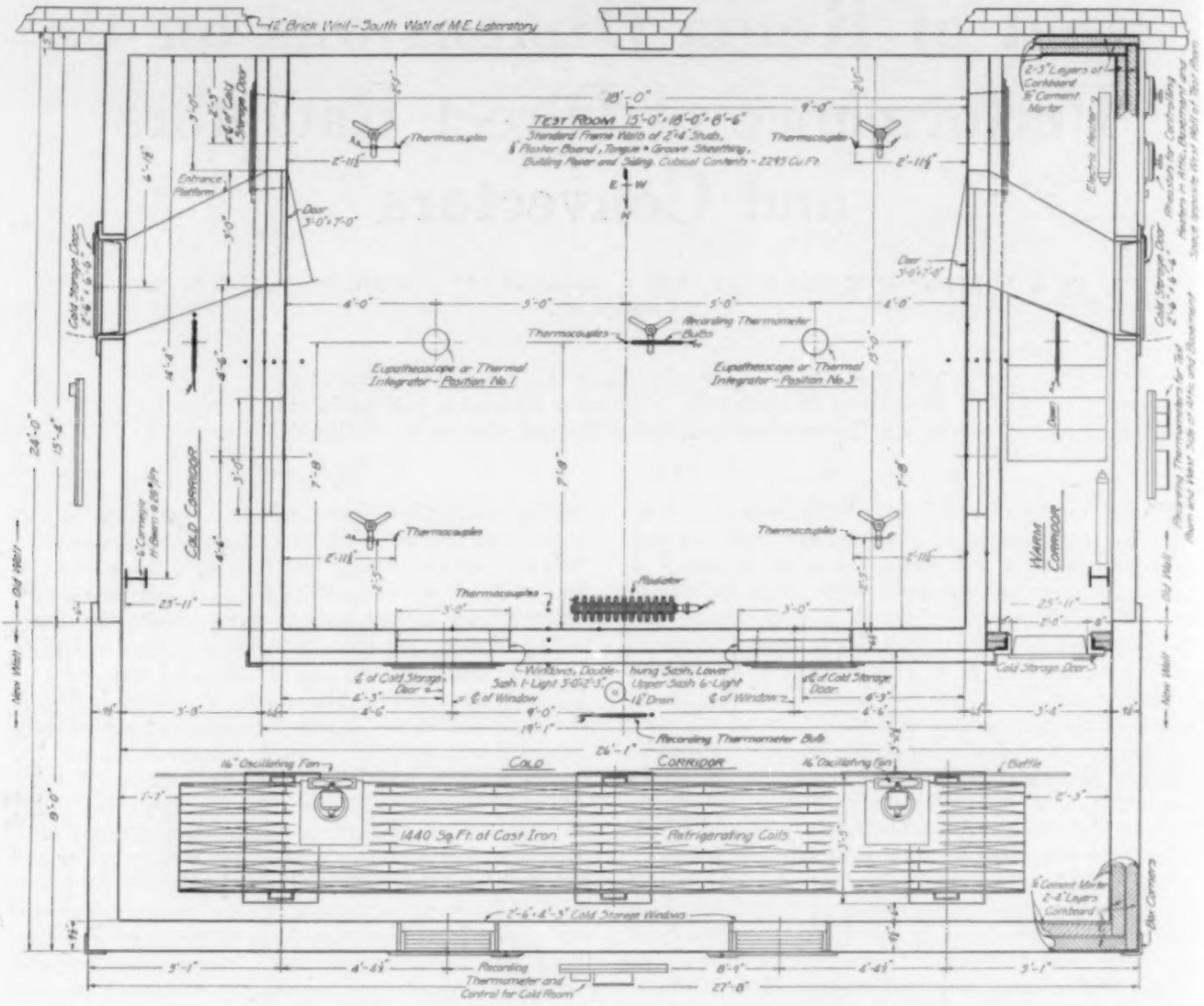

12" Brick Wall - South Wall of M.E. Laboratory
TEST ROOM 15'-0" x 18'-0" x 8'-6"
Standard Frame Walls of 2"x4" Studs, ½" Plaster Board, Tongue & Groove Sheathing, Building Paper and Siding. Cubical Contents - 2295 Cu. Ft.
Thermocouples
Recording Thermometer Bulbs
Eupatheoscope or Thermal Integrator - Position No. 1
Eupatheoscope or Thermal Integrator - Position No. 3
Radiator
Windows, Double-hung Sash, Lower Sash 1-Light 3'-0"x2'-3", Upper Sash 6-Light
18" Drain
Recording Thermometer Bulb
16" Oscillating Fan
COLD CORRIDOR
Baffle
1440 Sq. Ft. of Cast Iron Refrigerating Coils
2'-6"x4'-3" Cold Storage Windows
Recording Thermometer and Control for Cold Room
Cold Storage Door
Entrance Platform
Door 3'-0"x7'-0"
Electric Heaters
Warm Corridor
Old Wall
New Wall
27'-8"

Fig. 1—Plan section of room heating testing plant

all observations to be made without the necessity for entering the test room and thus disturbing conditions at any time during the test period. Thermocouples were located at various points on the inside and outside surfaces of the walls. Thermocouples for observing air temperatures were located 3 in. above the floor, 3 in. below the ceiling, at the 18 in., 30 in., and 60 in. levels in the room. Five sets of these thermocouples were supported on standards placed in the five positions shown in Fig. 1. These thermocouples were connected into a switch system so that they could be read separately, or the average of the five at any given level could be read directly. A thermo-integrator[7], shown in Fig. 3, and used for observing the equivalent and mean radiant temperatures was located in Position 3, as shown in Fig. 1.

The cast-iron radiators used in these tests consisted of: (1) a 13-section, 26 in., 5-tube radiator, with sections on 2½ in. centers; (2) an 18-section, 26 in., 3-tube radiator with sections on 2½ in. centers; and (3) a 25-section, 25 in., 3-tube radiator with sections on 1¾ in. centers. The convectors consisted of (1) a 5⅜ in. x 16⅛ in. cast-iron heating unit equipped with a cabinet 26 in. high and 69⅛ in. long; (2) a 5⅝ in. x 6 in. cast-iron heating unit equipped with a cabinet 26 in. high and 56⅞ in. long; and (3) a 5½ in. x 2½ in. non-ferrous heating unit equipped with a cabinet 26 in. high and 50 1/16 in. long. Details of all the radiators and convectors used in both test rooms are shown on the different curve sheets.

Test Procedure

In all cases the test room was operated with two walls exposed and the temperature in the cold room was maintained at from –1.0 to –3.0 F, with an equivalent wind velocity of approximately 10 mph over the north wall. The temperature of the air above the ceiling of the test room was maintained at 62 F, and the tempera-

[7]The Thermo-Integrator—A New Instrument for the Observation of Thermal Interchanges, by C-E. A. Winslow and Leonard Greenburg. (ASHVE Transactions, Vol. 41, 1935, p. 149.)

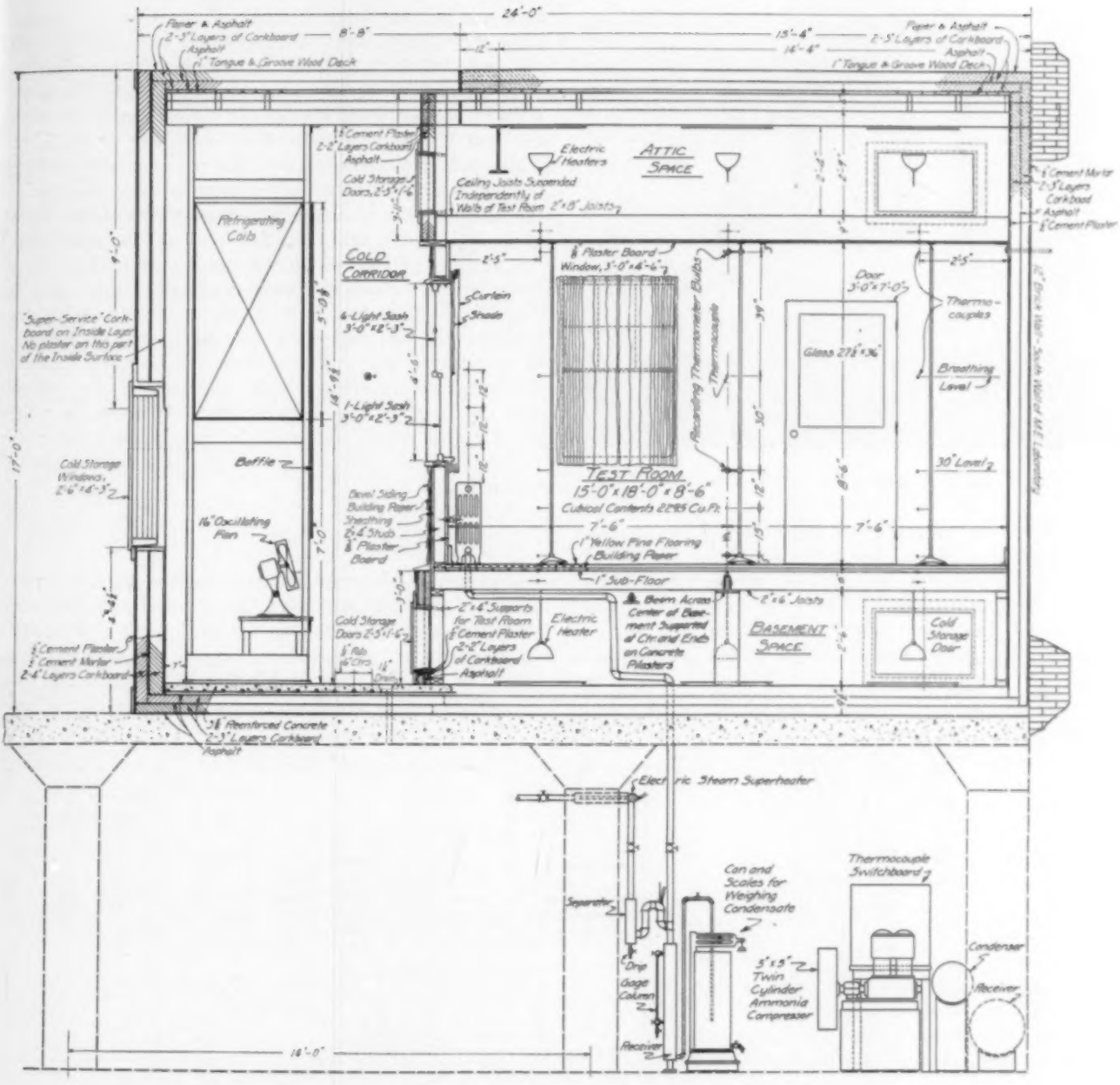


Fig. 2—Elevation section of room heating testing plant

ture of the upper surface of the floor was maintained from 1.0 to 1.5 F higher than that of the lower surface. All tests were run with two walls exposed and the inside surface of the wall between the test room and the closed west corridor was maintained at a temperature from 1.0 to 1.5 F higher than that of the outside surface. No test observations were made until conditions had remained constant for several hours, as indicated by the readings of the air temperature and that on the inside wall surfaces. A saturation temperature of 215 F was maintained for the steam in the test units, and when thermal constancy had been attained, the condensate was weighed over the period of one hour. Weighings were made at intervals of 10 min. The condensate was corrected by subtracting the condensation occurring in the piping alone, which was determined by separate tests.

Results of Tests

Performance in Large Test Room

The steam condensations and the temperature gradients produced in the room by the three radiators tested are shown in Fig. 4. Similar curves for the convectors are shown in Fig. 5. Details of both the radiators and the convectors are shown in the accompanying insets. For the purpose of comparison all of the units tested were operated to maintain a temperature of 68 F at the 30 in. level in the center of the room. Since it was not always possible to select commercial units of exactly the size required to maintain 68 F at the 30 in. level, units of somewhat larger size were installed, and, in the case of radiators the desired temperature was obtained by wrapping one or more sections with cloth.

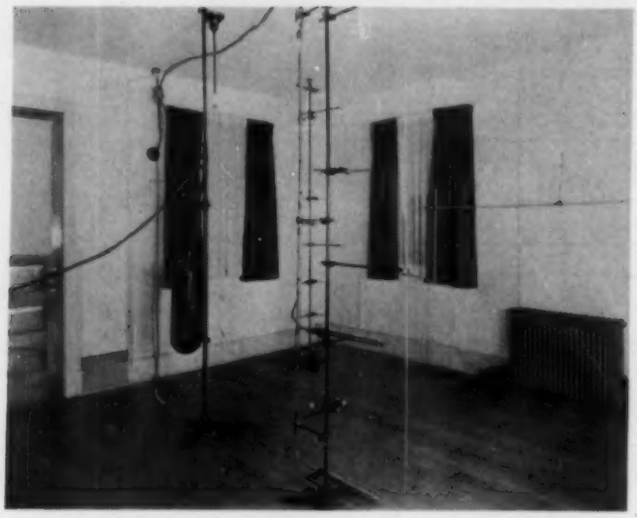


Fig. 3—The thermo-integrator inside of test room

In the case of convectors the desired result was obtained by blocking part of the heating unit and cabinet.

Fig. 4 shows that with the 26 in., 3-tube radiator, 18 sections were just sufficient to give a temperature of 68 F at the 30 in. level in the center of the room. The curves for the 26 in., 5-tube and the 25 in., 3-tube radiators indicate that in each case the effect of wrapping was to lower the temperature in the center of the room equally at all levels, and to decrease the steam condensation. That is, the new temperature gradients with some of the heating surfaces wrapped were parallel to the original ones, indicating that the wrapping had no disturbing effect, and that the wrapped radiators performed in essentially the same manner as unwrapped radiators of the correct size. The curves in Fig. 5 exhibited the same characteristics, thus indicating that a convector with a portion blocked also performed in essentially the same manner as an unblocked convector of the correct size.

In both Fig. 4 and Fig. 5 the minimum and maximum temperatures observed at the different levels in any of the positions of the thermocouples located on the 5 standards shown in Fig. 1 have been plotted, together with the temperatures observed in the vertical central axis of the room. The latter temperatures are represented by the heavy lines. The shaded areas represent the locus of the maximum deviations at any level from the temperature observed at the center of the room. It may be observed that in practically all cases the temperatures observed in the central axis represented the highest temperatures in the room. The maximum deviations in most cases occurred in the level nearest the floor and were of the order of 3½ F. The mean deviation was of the order of 2 F. Comparison of similar plots for wrapped and unwrapped radiators and blocked and unblocked convectors proved that the deviations were practically of the same magnitude and character whether the test units were of the correct size or whether the heat output was reduced by wrapping or blocking. This confirmed the conclusion that wrapping or blocking did not disturb either the temperature distribution or the temperature gradients produced in the room by a given type of test unit, and that comparisons made with the wrapped or blocked units were just as valid as those made with radiators or convectors of the correct size to maintain 68 F at the 30 in. level, as long as such comparisons did not involve the heat output per square foot of superficial area. The curves furthermore indicate that the temperature gradients observed in the central axis of the room were characteristic of those in other parts of the room, and could be validly used for comparisons of the performance of the different types of test units.

Effect of Size of Test Room

Comparisons between the temperature gradients produced in the small and large test rooms by radiators of three different types are shown in Fig. 6, and similar comparisons for three different types of convectors are shown in Fig. 7. In general it may be observed that the temperature near the floor in the large test room was

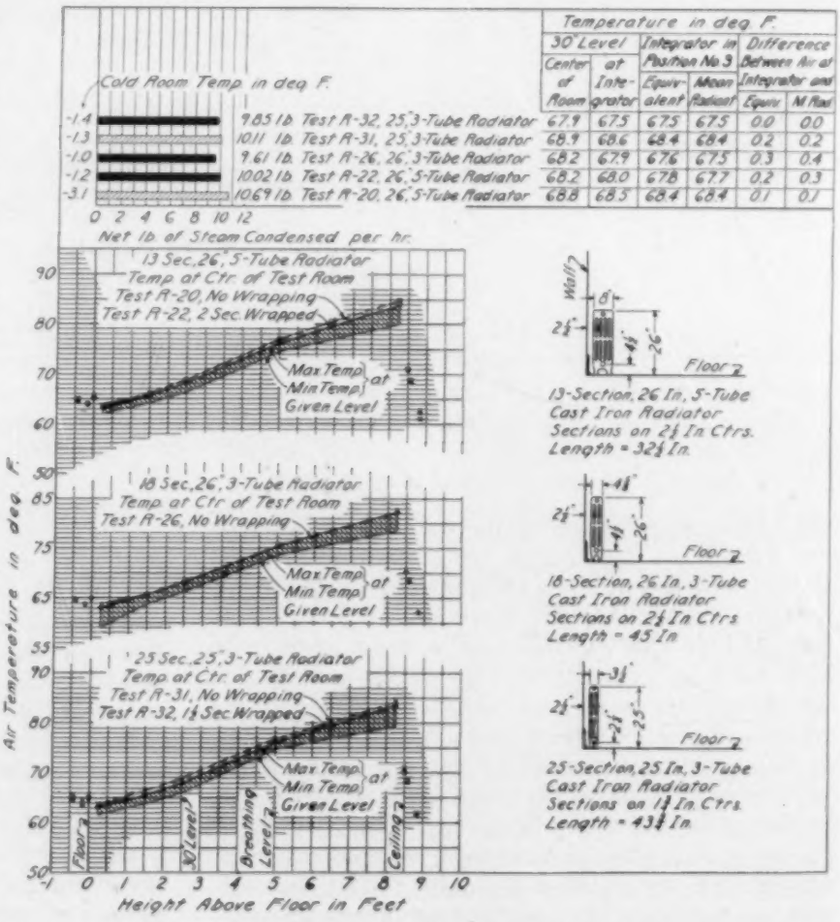

Temperature in deg. F.
30" Level
Integrator in Position No. 3
Difference Between Air at Integrator and
Center of Room
At Integrator
Equivalent Mean Radiant
Equiv.
Rad. Flux
Cold Room Temp. in deg. F.
-1.4 9.85 lb. Test R-32, 25, 3-Tube Radiator 67.9 67.5 67.5 67.5 0.0 0.0
-1.3 10.11 lb. Test R-31, 25, 3-Tube Radiator 68.9 68.6 68.4 68.4 0.2 0.2
-1.0 9.61 lb. Test R-26, 26, 3-Tube Radiator 68.2 67.9 67.6 67.5 0.3 0.4
-1.2 10.02 lb. Test R-22, 26, 5-Tube Radiator 68.2 68.0 67.8 67.7 0.2 0.3
-3.1 10.69 lb. Test R-20, 26, 5-Tube Radiator 68.8 68.5 68.4 68.4 0.1 0.1
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
13 Sec., 26", 5-Tube Radiator
Temp. at Ctr. of Test Room
Test R-20, No Wrapping
Test R-22, 2 Sec. Wrapped
Max Temp. at Min Temp. Given Level
18 Sec., 26", 3-Tube Radiator
Temp. at Ctr. of Test Room
Test R-26, No Wrapping
25 Sec., 25", 3-Tube Radiator
Temp. at Ctr. of Test Room
Test R-31, No Wrapping
Test R-32, 1½ Sec. Wrapped
Air Temperature in deg. F.
Floor
30" Level
Breathing Level
Ceiling
Height Above Floor in Feet
Wall
Floor
13-Section, 26 In., 5-Tube Cast Iron Radiator Sections on 2½ In. Ctrs. Length = 32½ In.
18-Section, 26 In., 3-Tube Cast Iron Radiator Sections on 2½ In. Ctrs. Length = 45 In.
25-Section, 25 In., 3-Tube Cast Iron Radiator Sections on 1¾ In. Ctrs. Length = 43¾ In.

Fig. 4—Performance curves for three types of direct cast-iron radiators in 15 ft x 18 ft x 8 ft-6 in. test room

approximately 4 F higher than that in the small room, while the temperature near the ceiling was from 1.0 to 3.0 F higher than that in the small room. With one exception this resulted in somewhat smaller temperature differences between the ceiling and floor in the large test room, as shown in Table 1. The last column of this table indicates that the effect of the large room was more marked in the case of convectors than it was in the case of direct radiators.

The higher temperature near the floor of the large test room was probably brought about by the fact that any air inleakage occurring at the door was less effective at the center of the large room than it was at the center of the small room. In general there was a tendency for the temperature near the ceiling of the large test room to be equal to or greater than that for the small room. In any event the magnitudes of the temperature differences between the ceiling and floor obtained with the different units in the large and the small test rooms were approximately of the same order and the deviations between the effects of the two rooms do not seem sufficient to invalidate any of the conclusions drawn in previous publications[8] from tests made in the small room.

From Figs. 6 and 7 it may be observed that in general the differences in steam condensation obtained from different units tested in the large room were considerably less than the corresponding differences obtained from the same types of units tested in the small room. Apparently, therefore, the small test room tended to accentuate any difference in performance existing between units of different types.

Effect of Type on the Performance of Radiators and Convectors

In a previous paper[9] it was indicated that when radiators or convectors were operated to maintain a temperature of 68 F at the 30 in. level in the test room, the units represented by the temperature gradient curves having the lesser slope above the 30 in. level also gave the lower steam condensations. In Fig. 8 the curves and data have been shown in groups arranged to make possible a direct comparison of the performance of the different types of radiators tested in each of the two test rooms. Similar data for the convectors are shown in Fig. 9. In the latter case data for the performance of the 25 in., 5-tube radiator have also been added for the purpose of comparison.

From Fig. 8 it may be observed that, in the small test room, the temperature gradient curves in descending order were designated as, 26 in., 5-tube and 26 in., 3-tube, with steam condensations of 6.23 and 5.87 lb per hour respectively. In the large test room the temperature gradient curves in descending order were designated as 26 in., 5-tube, 25 in., 3-tube and 26 in. 3-tube, with steam condensations of 10.02, 9.85 and 9.61 lb per hour respectively. That is, the steam condensations were consistently in the order of the arrangement of the corresponding temperature gradient curves above the 30 in. level.

From Fig. 9 it may be observed that, in the small test room, the temperature gradient curves in the descending order were designated as Convector No. 6, 26 in., 5-tube radiator, and Convector No. 1 with steam condensations of 6.02, 6.23 and 5.50 lb per hour respectively. In this case there was a slight inconsistency in the location of the upper part of the curve for the radiator which was used to designate the location of the curves. However, if the lower section of the curve for the radiator were taken into consideration the inconsistency is not so marked. The curves and steam condensations for the convectors showed consistent correlation in the arrangement. In the large test room the temperature gradient curves in the descending order were designated as, 26 in., 5-tube radiator, Convector No. 44, Convector No. 43, and Convector No. 42 with corresponding steam condensations of 10.02, 9.33, 9.22 and 9.29 lb per hour respectively. Convector No. 44 was of

[8]Loc. Cit. Notes 1-5.

[9]Loc. Cit. Note 3.

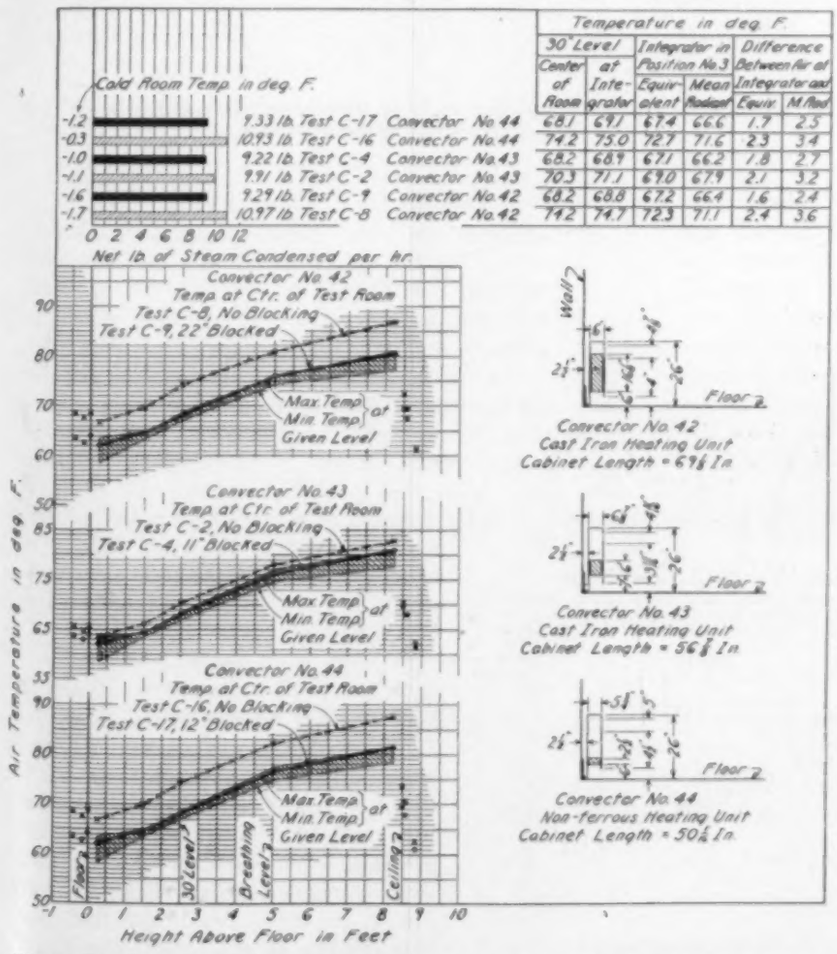

Temperature in deg. F.
30" Level
Integrator in Position No. 3
Difference Between Air at Integrator and
Center of Room
at Integrator
Equivalent
Mean Radiant
Equiv.
M.Rad.
Cold Room Temp. in deg. F.
-1.2 9.33 lb. Test C-17 Convector No. 44 68.1 69.1 67.4 66.6 1.7 2.5
-0.3 10.93 lb. Test C-16 Convector No. 44 74.2 75.0 72.7 71.6 2.3 3.4
-1.0 9.22 lb. Test C-4 Convector No. 43 68.2 68.9 67.1 66.2 1.8 2.7
-1.1 9.91 lb. Test C-2 Convector No. 43 70.3 71.1 69.0 67.9 2.1 3.2
-1.6 9.29 lb. Test C-9 Convector No. 42 68.2 68.8 67.2 66.4 1.6 2.4
-1.7 10.97 lb. Test C-8 Convector No. 42 74.2 74.7 72.3 71.1 2.4 3.6
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
Convector No. 42
Temp. at Ctr. of Test Room
Test C-8, No Blocking
Test C-9, 22" Blocked
Max. Temp. at Min. Temp. Given Level
Convector No. 43
Temp. at Ctr. of Test Room
Test C-2, No Blocking
Test C-4, 11" Blocked
Max. Temp. at Min. Temp. Given Level
Convector No. 44
Temp. at Ctr. of Test Room
Test C-16, No Blocking
Test C-17, 12" Blocked
Max. Temp. at Min. Temp. Given Level
Air Temperature in deg. F.
Floor
30" Level
Breathing Level
Ceiling
Height Above Floor in Feet
Wall
Floor
Convector No. 42
Cast Iron Heating Unit
Cabinet Length = 67½ In.
Convector No. 43
Cast Iron Heating Unit
Cabinet Length = 56½ In.
Convector No. 44
Non-ferrous Heating Unit
Cabinet Length = 50½ In.

Fig. 5—Performance curves for three types of convectors in 15 ft x 18 ft x 8 ft-6 in. test room

the same general type as Convector No. 6, and Convector No. 42 was of the same type as Convector No. 1. In this case the location of the temperature gradient curves was not exactly consistent with the steam condensations shown for the convectors. Since the differences under consideration were very small it is not surprising that a few inconsistencies might occur. On the whole, however, the results confirm the previous conclusion that the lesser temperature gradients are accompanied by the lower steam condensations. Furthermore while tests made in the small test room tend to accentuate differences in the performance characteristics of different types or proportions of radiators and convectors, results obtained in the large test room are in the main consistent with those obtained in the small test room.

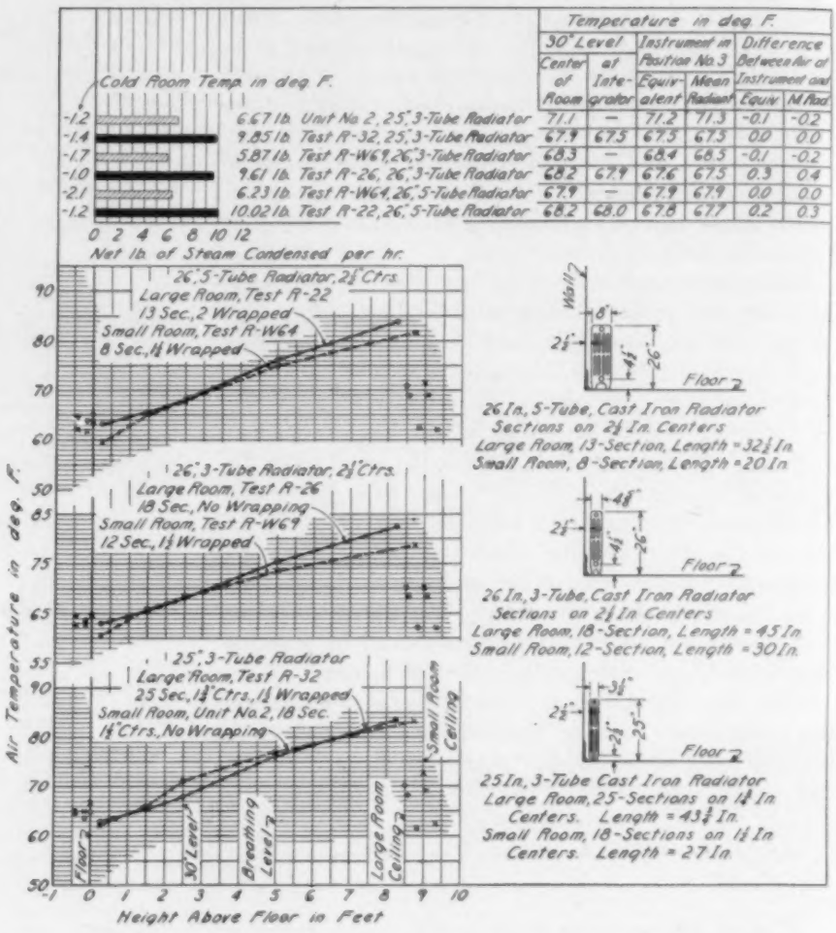

Temperature in deg. F.
30" Level
Instrument in Position No. 3
Difference Between Air at Instrument and
Center of Room
at Integrator
Equivalent
Mean Radiant
Equiv.
M.Rad.
Cold Room Temp. in deg. F.
-1.2 6.67 lb. Unit No. 2, 25" 3-Tube Radiator 71.1 — 71.2 71.3 -0.1 -0.2
-1.4 9.85 lb. Test R-32, 25" 3-Tube Radiator 67.9 67.5 67.5 67.5 0.0 0.0
-1.7 5.87 lb. Test R-W69, 26" 3-Tube Radiator 68.3 — 68.4 68.5 -0.1 -0.2
-1.0 9.61 lb. Test R-26, 26" 3-Tube Radiator 68.2 67.9 67.6 67.5 0.3 0.4
-2.1 6.23 lb. Test R-W64, 26" 5-Tube Radiator 67.9 — 67.9 67.9 0.0 0.0
-1.2 10.02 lb. Test R-22, 26" 5-Tube Radiator 68.2 68.0 67.8 67.7 0.2 0.3
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
26", 5-Tube Radiator, 2½" Ctrs.
Large Room, Test R-22
13 Sec., 2 Wrapped
Small Room, Test R-W64
8 Sec., ¼ Wrapped
26", 3-Tube Radiator, 2½" Ctrs.
Large Room, Test R-26
18 Sec., No Wrapping
Small Room, Test R-W69
12 Sec., ⅛ Wrapped
25", 3-Tube Radiator
Large Room, Test R-32
25 Sec., 1¾" Ctrs., ¼ Wrapped
Small Room, Unit No. 2, 18 Sec.
1¼" Ctrs., No Wrapping
Air Temperature in deg. F.
Floor
30" Level
Breathing Level
Large Room Ceiling
Small Room Ceiling
Height Above Floor in Feet
Wall
Floor
26 In., 5-Tube, Cast Iron Radiator
Sections on 2½ In. Centers
Large Room, 13-Section, Length = 32½ In.
Small Room, 8-Section, Length = 20 In.
26 In., 3-Tube, Cast Iron Radiator
Sections on 2½ In. Centers
Large Room, 18-Section, Length = 45 In.
Small Room, 12-Section, Length = 30 In.
25 In., 3-Tube Cast Iron Radiator
Large Room, 25-Sections on 1¾ In. Centers. Length = 43¾ In.
Small Room, 18-Sections on 1¼ In. Centers. Length = 27 In.

Fig. 6—Performance curves for three types of direct cast-iron radiators in 15 ft x 18 ft x 8 ft-6 in. and 9 ft x 11 ft x 9 ft test rooms

Equivalent and Mean Radiant Temperatures

The equivalent temperature of a nonuniform environment may be defined as the temperature of a uniform environment, which will result in the same heat loss from a sizable body at a given body surface temperature as that which was obtained from the same body in the nonuniform environment under consideration. A uniform environment is one in which the air and all radiating surfaces are at the same temperature. A nonuniform environment is one in which the air and all or part of the radiating surfaces are at different temperatures. The mean radiant temperature of an environment in which a body is losing heat at a given body surface temperature is an hypothetical temperature, representing the temperature of completely enclosing surfaces all at the same temperature, which would result in the same heat loss by radiation as that occurring from the given body in the given environment. The equivalent and mean radiant temperatures shown in Figs. 4 to 9 were obtained by using a thermo-integrator[10] in Position No. 3 shown in Fig. 1.

The equivalent and mean radiant temperatures shown in Figs. 8 and 9 were all obtained under the same conditions, with 68 F at the 30 in. level, and hence afford the best means for comparing the results given by direct radiators and convectors. The equivalent temperature, to a limited extent, correlates with the comfort chart. An equivalent temperature of 72 F with relative humidity of 25 per cent roughly correlates[11] with an effective temperature of 66 F. Equivalent temperatures lower than this probably indicate an environment too cold for comfort, and those higher an environment too warm. Data are lacking to exactly correlate these equivalent temperatures with effective temperatures below and above 66 F.

Equivalent temperatures obtained with the direct radiators, as shown in Fig. 7, were all within 0.3 F of the air temperature while those obtained with the convectors were from 1.4 F to 1.8 F lower than the air temperature. Thus, while none of the units produced an equivalent temperature that was sufficient for maximum comfort at the 30 in. level with the same temperature at this level, the direct

Table 1—Temperature Difference Between Air at Ceiling and Floor

Description of Radiators and Convectors		Test No.	Temp. Diff. Between Ceiling and Floor at Center of Room in Deg F		Decrease in Temp. Diff. Obtained in Large Room Deg F
			Small Room	Large Room	
Cast-Iron Radiator	26-in., 5-tube	R-W64	22.1		1.5
	26-in., 5-tube	R-22		20.6	
Cast-Iron Radiator	26-in., 3-tube	R-W69	18.2		—1.2
	26-in., 3-tube	R-26		19.4	
Cast-Iron Radiator	25-in., 3-tube	Unit No. 2	21.1		0.6
	25-in., 3-tube	R-32		20.5	
Convector Cast-Iron Heating Unit	No. 1, 5¾ in. x 14¼ in.	I-W101	20.8		2.4
	No. 42, 5¾ in. x 16½ in.	C-9		18.4	
Convector Cast-Iron Heating Unit	No. 32, 5¾ in. x 6 in.	Unit No. 3	23.9		5.0
	No. 43, 5¾ in. x 6 in.	C-4		18.9	
Convector Non-Ferrous Heating Unit	No. 6, 5¾ in. x 2 in.	I-W74	24.1		4.7
	No. 44, 5½ in. x 2½ in.	C-17		19.4	

[10] Loc. Cit. Note 7.
[11] Loc. Cit. Note 5.

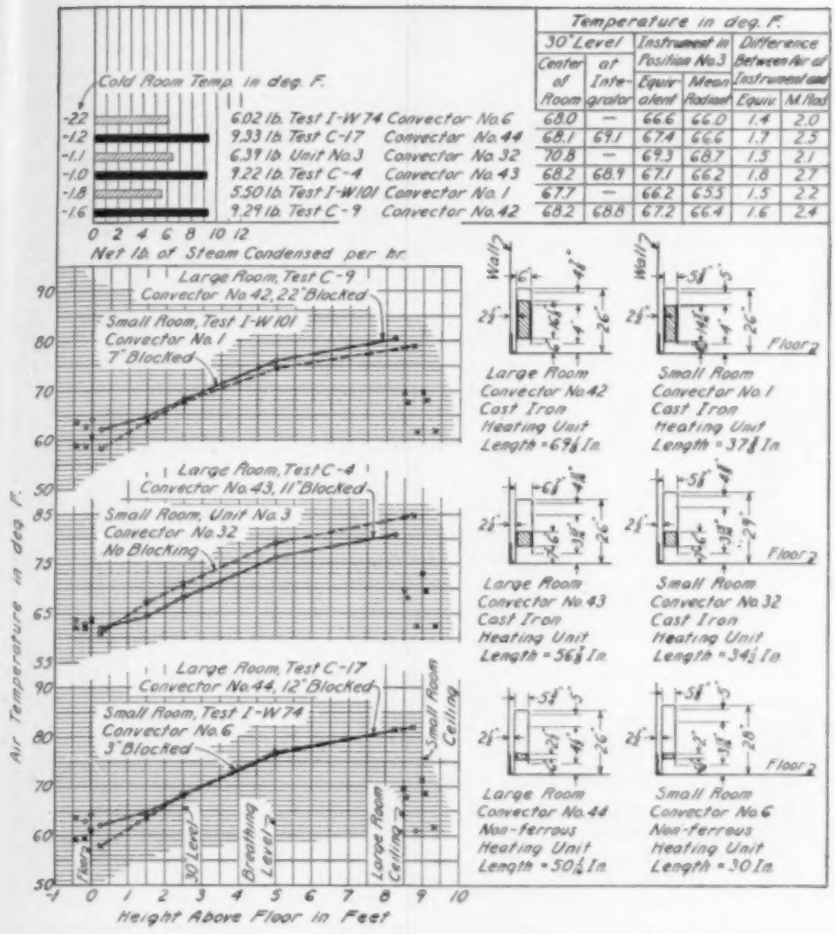

Temperature in deg. F.
30" Level
Instrument in Position No. 3
Difference Between Air at Instrument and
Center of Room
at Integrator
Equivalent
Mean Radiant
Equiv.
M. Rad.
Cold Room Temp. in deg. F.
-2.2
-1.2
-1.1
-1.0
-1.8
-1.6
6.02 lb. Test I-W 74 Convector No. 6
9.33 lb. Test C-17 Convector No. 44
6.39 lb. Unit No. 3 Convector No. 32
9.22 lb. Test C-4 Convector No. 43
5.50 lb. Test I-W101 Convector No. 1
9.29 lb. Test C-9 Convector No. 42
68.0 — 66.6 66.0 1.4 2.0
68.1 69.1 67.4 66.6 1.7 2.5
70.8 — 69.3 68.7 1.5 2.1
68.2 68.9 67.1 66.2 1.8 2.7
67.7 — 66.2 65.5 1.5 2.2
68.2 68.8 67.2 66.4 1.6 2.4
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
Large Room, Test C-9
Convector No. 42, 22" Blocked
Small Room, Test I-W 101
Convector No. 1
7" Blocked
Large Room, Test C-4
Convector No. 43, 11" Blocked
Small Room, Unit No. 3
Convector No. 32
No Blocking
Large Room, Test C-17
Convector No. 44, 12" Blocked
Small Room, Test I-W 74
Convector No. 6
3" Blocked
Air Temperature in deg. F.
Floor
30" Level
Breathing Level
Large Room Ceiling
Small Room Ceiling
Height Above Floor in Feet
Large Room Convector No. 42 Cast Iron Heating Unit Length = 69⅛ In.
Small Room Convector No. 1 Cast Iron Heating Unit Length = 37⅛ In.
Large Room Convector No. 43 Cast Iron Heating Unit Length = 56⅝ In.
Small Room Convector No. 32 Cast Iron Heating Unit Length = 34⅛ In.
Large Room Convector No. 44 Non-ferrous Heating Unit Length = 50¼ In.
Small Room Convector No. 6 Non-ferrous Heating Unit Length = 30 In.

Fig. 7—Performance curves for three types of convectors in 15 ft x 18 ft x 8 ft-6 in. and in 9 ft x 11 ft x 9 ft test rooms

radiation from the radiators tended to create an environment that was slightly more comfortable than that produced by the convectors.

As shown in Fig. 8, the mean radiant temperatures obtained with the direct radiators were also all within 0.4 F of the air temperature, indicating that the direct radiation from the hot surfaces was sufficient to practically offset the chilling effect of the cold walls and windows of the test room. In the case of convectors, however, the mean radiant temperature was from 2.0 F to 2.7 F lower than the air temperature, indicating that the absence of direct radiation from hot surfaces resulted in a predominance of the chilling effect of the cold walls and windows of the room.

Conclusions

The following conclusions may be drawn from the results of these tests:

1. The use of a test room as small as 9 ft x 11 ft x 9 ft tends to accentuate differences in performance inherent in radiators and convectors of different types or proportions.

2. The use of a test room as large as 15 ft x 18 ft x 8 ft-6 in. tends to reduce differences in performance inherent in radiators and convectors of different types or proportions, but does not alter the performance characteristics sufficiently to materially affect conclusions drawn from similar tests made in a smaller test room.

3. Radiators or convectors which produce the smallest temperature gradients, or the least temperature differences between the air near the ceiling and that near the floor, while maintaining a temperature of 68 F at the 30 in. level, also tend to give the smallest steam condensations.

4. With an air temperature of 68 F at the 30 in. level, neither radiators nor convectors give equivalent temperatures sufficiently high for maximum comfort at this level. The equivalent temperature given by radiators is somewhat higher than that given by convectors.

5. In some parts of the room the direct radiation from radiators is sufficient to offset the chilling effect of cold walls, but with convectors the chilling effect of the walls and windows is a predominant factor.

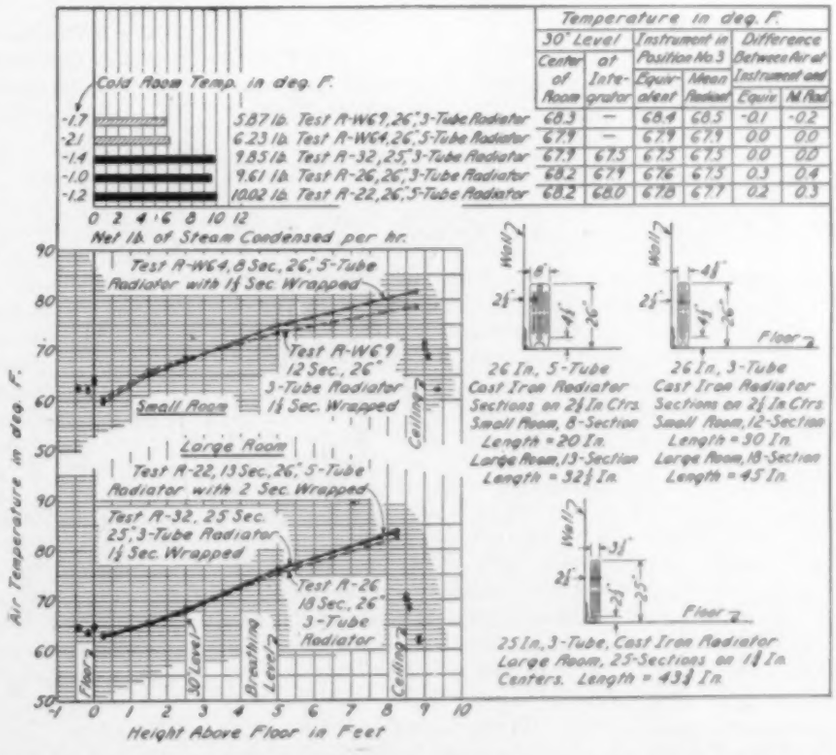
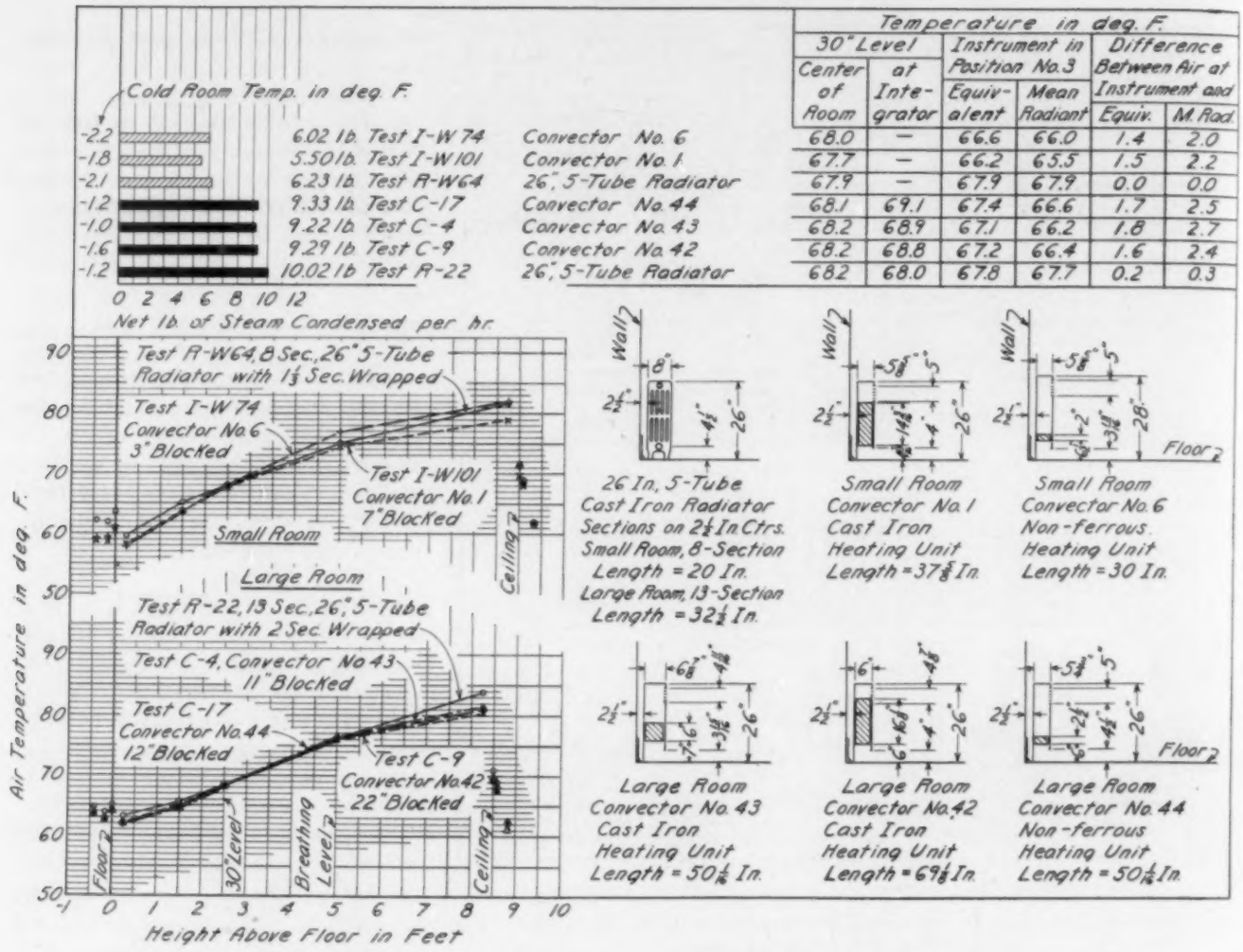

Temperature in deg. F.
30" Level
Instrument in Position No. 3
Difference Between Air at Instrument and
Center of Room
at Integrator
Equivalent
Mean Radiant
Equiv.
M. Rad.
Cold Room Temp. in deg. F.
-1.7
-2.1
-1.4
-1.0
-1.2
5.87 lb. Test R-WC9, 26", 3-Tube Radiator
6.23 lb. Test R-WC4, 26", 5-Tube Radiator
9.85 lb. Test R-32, 25", 3-Tube Radiator
9.61 lb. Test R-26, 26", 3-Tube Radiator
10.02 lb. Test R-22, 26", 5-Tube Radiator
68.3 — 68.4 68.5 -0.1 -0.2
67.9 — 67.9 67.9 0.0 0.0
67.9 67.5 67.5 67.5 0.0 0.0
68.2 67.9 67.6 67.5 0.3 0.4
68.2 68.0 67.8 67.7 0.2 0.3
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
Test R-WC4, 8 Sec., 26", 5-Tube Radiator with 1½ Sec. Wrapped
Test R-WC9 12 Sec., 26" 3-Tube Radiator 1½ Sec. Wrapped
Small Room
Large Room
Test R-22, 13 Sec., 26", 5-Tube Radiator with 2 Sec. Wrapped
Test R-32, 25 Sec. 25", 3-Tube Radiator 1½ Sec. Wrapped
Test R-26 18 Sec., 26" 3-Tube Radiator
Air Temperature in deg. F.
Floor
30" Level
Breathing Level
Ceiling
Height Above Floor in Feet
26 In., 5-Tube Cast Iron Radiator Sections on 2½ In. Ctrs. Small Room, 8-Section Length = 20 In. Large Room, 13-Section Length = 32½ In.
26 In., 3-Tube Cast Iron Radiator Sections on 2½ In. Ctrs. Small Room, 12-Section Length = 30 In. Large Room, 18-Section Length = 45 In.
25 In., 3-Tube, Cast Iron Radiator Large Room, 25-Sections on 1½ In. Centers. Length = 43½ In.

Fig. 8—Comparison of performance curves for three types of direct cast-iron radiators


Cold Room Temp. in deg. F.
-2.2
-1.8
-2.1
-1.2
-1.0
-1.6
-1.2
6.02 lb. Test I-W 74
5.50 lb. Test I-W 101
6.23 lb. Test A-W64
9.33 lb. Test C-17
9.22 lb. Test C-4
9.29 lb. Test C-9
10.02 lb. Test A-22
Convector No. 6
Convector No. 1
26", 5-Tube Radiator
Convector No. 44
Convector No. 43
Convector No. 42
26", 5-Tube Radiator
0 2 4 6 8 10 12
Net lb. of Steam Condensed per hr.
Air Temperature in deg. F.
Test A-W64, 8 Sec., 26" 5-Tube Radiator with 1⅓ Sec. Wrapped
Test I-W 74 Convector No. 6 3" Blocked
Test I-W101 Convector No. 1 7" Blocked
Small Room
Large Room
Test A-22, 13 Sec., 26", 5-Tube Radiator with 2 Sec. Wrapped
Test C-4, Convector No. 43 11" Blocked
Test C-17 Convector No. 44 12" Blocked
Test C-9 Convector No. 42 22" Blocked
Floor
30" Level
Breathing Level
Ceiling
Height Above Floor in Feet
Wall
Floor
26 In., 5-Tube Cast Iron Radiator Sections on 2½ In. Ctrs. Small Room, 8-Section Length = 20 In. Large Room, 13-Section Length = 32½ In.
Small Room Convector No. 1 Cast Iron Heating Unit Length = 37⅝ In.
Small Room Convector No. 6 Non-ferrous Heating Unit Length = 30 In.
Large Room Convector No. 43 Cast Iron Heating Unit Length = 50½ In.
Large Room Convector No. 42 Cast Iron Heating Unit Length = 69⅛ In.
Large Room Convector No. 44 Non-ferrous Heating Unit Length = 50½ In.

Temperature in deg. F.					
30" Level		Instrument in Position No. 3		Difference Between Air at Instrument and	
Center of Room	at Integrator	Equivalent	Mean Radiant	Equiv.	M. Rad.
68.0	—	66.6	66.0	1.4	2.0
67.7	—	66.2	65.5	1.5	2.2
67.9	—	67.9	67.9	0.0	0.0
68.1	69.1	67.4	66.6	1.7	2.5
68.2	68.9	67.1	66.2	1.8	2.7
68.2	68.8	67.2	66.4	1.6	2.4
68.2	68.0	67.8	67.7	0.2	0.3

Fig. 9—Comparison of performance curves for three types of convectors

Acknowledgment

The data presented in this paper were obtained in connection with an investigation conducted by the Engineering Experiment Station of the University of Illinois in cooperation with the American Society of Heating and Ventilating Engineers. This work is carried on in the Department of Mechanical Engineering. The results will ultimately comprise part of a bulletin of the Engineering Experiment Station.

Research on Preservation of Records

The results of systematic studies of the problem of preserving valuable records are summarized by A. E. Kimberly and B. W. Scribner in *National Bureau of Standards* miscellaneous publication M154 entitled Summary Report of National Bureau of Standards Research on Preservation of Records.

A survey of material stored in libraries and of the surrounding conditions, showed that many valuable publications were badly deteriorated. Light, adverse temperature and humidity, acidic pollution of the air, and impurities in paper were indicated as the main deteriorative agents. Through exposures of papers to sulphur dioxide gas, with measurement of the weakening effect, and the testing of papers from old books that had been stored in various localities, this product of combustion was proved a potential destroyer of all classes of papers. Experimental tests in a library demonstrated that this acidic gas can be completely removed by washing the air with alkaline water. The destructive effect of light is emphasized by data showing its rapid weakening effect on all grades of papers. In the discussion of the ventilation of libraries, the removal of dust, and the maintenance of a medium degree of temperature and humidity are recommended Carefully controlled air conditioning is desirable. Extensive tests of old newspapers and books showed the deteriorative effect of crude fibers, such as ground wood; papers containing them were generally in bad condition as contrasted with the generally good condition of papers composed of chemically purified fibers. A classification of book papers for record use is suggested. Relative to protection against insects, the results of a study of fumigants showed that several effective types could be used without damaging paper. Studies of protective coatings for papers indicated that both Japanese tissue and transparent cellulose acetate sheeting are suitable. The common type of writing ink was found to be deteriorative to paper, but an ink prepared according to a different formula had a negligible effect. For preservation by reproduction, photostat prints on permanent paper were found suitable, and tests of cellulose acetate film indicated that it offered considerable promise for the purpose.

These investigations were made with the assistance of a fund granted to the National Research Council by the Carnegie Foundation. The study of films was partially supported by the National Archives.

Methods of Rating the Noise from Air Conditioning Equipment

By J. S. Parkinson,* (*MEMBER*), Manville, N. J.

NOISE is a factor which must be considered in rating the performance of a piece of equipment which is to be used in conjunction with living or working spaces. There is an increasing need for procedures to rate the performance of apparatus in terms of its noise generation. This state of affairs arises partly from the increasing public consciousness of noise, and partly because the success of other quieting measures requires that machinery noise be considered as an integral part of the whole design problem.

A noise rating is useful to determine whether equipment will meet a given specification, and how it compares with other makes; it also provides an index for determining how much noise need be tolerated in the completed installation. As there is now available quite a large amount of data which describes tolerable or acceptable noise levels in various locations, it is desirable and reasonable to know whether the equipment will keep within specified limits.

The ASHVE Research Technical Advisory Committee on Sound Control recognizes the requirements of engineers engaged in the heating, ventilating and air conditioning fields and has studied the problems relating to normal or acceptable noise levels, and the necessity of rating apparatus noise for the use of the maker, designer, installer and user of mechanical equipment. In this discussion some of the committee's findings will be reviewed, the need for further data will be pointed out and the need of a test code will be outlined.

Considering the merits of the various proposals for rating apparatus noise the following three items are of importance: *first*, what is to be measured; *second*, what apparatus or equipment is to be used in the measurement; *third*, how are the results to be expressed? In this problem the only serious controversy is in regard to the third point.

The measurement of noise emitted by ventilating and air conditioning equipment under normal conditions of use can be divided into two classes: (1) unitary equipment intended for use in the room itself, and (2) remotely located equipment. This latter appears to involve measuring the noise radiated into the equipment room as well as that emitted into the duct connections. It likewise requires a measurement of the noise generated in the duct system itself and at the outlets.

Apparatus for measuring the noise has to a large extent already been standardized by the Committee on Acoustical Measurements and Terminology of the *American Standards Association* and three bulletins on terminology, noise measurement, and sound level meters[1] are generally available. A standard sound level meter with a microphone suitable for purposes of exploration plus, in certain cases, a frequency analyzer, are probably all that are needed.

The studies of the ASHVE committee with respect to the room in which the measurements are to be made have produced the following facts:

In rating noise that is radiated directly, the apparatus should be placed in a space substantially free from reflection effects at the room boundaries. This requires a space whose dimensions are at least three times the corresponding dimensions of the equipment. Larger rooms are preferable where space is available. The walls and ceiling of the space should be made sound absorbent to a point where the average reflection coefficient is less than 10 per cent. If this requirement cannot be met, the level as measured at a point remote in the room should be at least 10 db below that at the point of measurement. The floor is assumed to be reflecting. An exception to this may be made if the equipment is normally installed against a wall or other surface adapted to reflect sound.

All measurements should be stated as pressure levels in decibels or loudness levels in phons.

As the method of expressing the results of noise measurements is the vital point involved in the several codes already suggested to industry, that recently adopted by the *AIEE* may be considered as typical. This code specifies the general conditions under which the noise measurement is to be made and then proposes the adoption of a series of individual or sub-codes for specific types of apparatus. In the general code, the measurement is usually made by placing the microphone of the sound level meter at a fixed distance and a fixed position with reference to the apparatus. Under these circumstances if equivalent sound level meters and equivalent sound testing rooms are used, the measurements are comparative. Such measurements, however, must be made reasonably close to the equipment to insure proper accuracy. Distances from 6 to 8 in. are common.

This method of procedure can be seriously questioned because of the fact that the decibel level so measured has no relation to the sound level which the user will hear. The occupant of a space will not ordinarily be close to the apparatus. Furthermore, the level which he hears will be a function of two quantities; one, the total noise energy given off by the equipment, and two, the acoustical properties of the room in which he and the apparatus are located. For example, if a man selects a desk fan, and is informed of the sound level 15 in. from the fan, such knowledge is of no value to him. Such a fan might be a definite noise nuisance in a quiet private office where the background level and acoustic absorption were low, whereas it would not be a noise hazard at all in a large general office where the back-

*Research Engineer, Johns-Manville Research Laboratories.

[1] *American Tentative Standards* Z24.1, 24.2 and 24.3.

Presented at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Washington, D. C., June, 1940.

ground level was high and the absorption was considerable.

It appears, then, that the single point measurement, while satisfactory for many purposes, is not adequate for general use. The author therefore would propose a method of rating which will indicate how much noise is radiated by the apparatus into the surrounding atmosphere in unit time, *i.e.* total sound power. Such a measurement can be made by taking a series of ten readings over an imaginary hemisphere of reference around the equipment and thereby obtaining a summation of the radiant energy. With this quantity known, it is possible to compute the average noise level which will be generated in any space from an estimate of acoustic absorption of that space.

The formula which relates these quantities is:

$$I = \frac{E}{\Sigma as} \quad \ldots\ldots (1)$$

where:

I = the average sound energy flux
E = the power output of the source
Σas = the total absorbing power of the room

This may also be written

$$L = 10 \log_{10} \left(\frac{E}{\Sigma as\, I_o} \right) \quad \ldots\ldots (2)$$

where L = the corresponding intensity level in decibels
I_o = the threshold reference intensity ($=10^{-16}$ watts/cm^2)

The intensity level thus computed may in turn be converted to the loudness level required in the code by the use of the equal loudness contours contained in the *ASA* tentative standards, providing that some indication of the predominant frequencies can be obtained.

In order to check the procedure outlined in actual practice, three small pieces of apparatus were studied and the rating is given in terms of their total sound power output in a dead room which corresponded to the code requirements. The average noise levels set up in three other spaces of widely varying acoustic properties were then measured. The acoustic absorption of these spaces was estimated and the level predicted from the formula compared with that actually obtained. Tables 1, 2 and 3 show the results.

It will be seen that the maximum error involved is of the order of ± 2 db and the average error is only 0.1 db. The measurements were made rapidly, taking a minimum number of microphone positions (ten in each room) and only a rough estimate of the sound absorption of each room was made, except in the case of the reverberation chamber, where an accurate calibration was available. In other words, the results are typical of what might readily be obtained in practice.

There are certain potential errors in this method of procedure. In making the original hemisphere measurements with a pressure microphone, there will be places where as a result of interference the readings will not be entirely representative. Normally, by averaging a considerable number of readings, such errors will cancel themselves out. It will be noted that one of the small experimental pieces used was an oil pump, which with its pipe lines and tank presented a very complex surface. The fact that the hemisphere measurement on this unit gave accurate data on which to base calculations appears to indicate that complicated shapes are not necessarily a serious obstacle in this type of measurement.

It is possible that some new difficulties might be encountered in rating larger types of equipment, particularly where the dimensions are considerably larger than the wave-lengths of the sound given off. In this case, however, there seems to be no reason why the radius of the hemisphere of reference should not be varied, since the length of this radius has no effect upon the usefulness of the measurement. It should be possible to check the total sound power output from several such hemispheres and thus determine the relative reliability of any given radius.

It should be particularly noted that the success of the sound level predictions depends upon a knowledge of the frequency distribution of the noise. The acoustic

Table 1—Noise Level of Small Motor

Apparatus	¼ horsepower electric motor—3600 RPM Mounted on slab of 1 in. insulating board Dimensions—approximately 7 in. diameter—length 10 in. including pulley.
Data	Total sound power = 18.5 microwatts (hemisphere radius = 9 in.) Significant frequency bands = 200-800 cps Selected mean frequency = 500 cps

Test Room Measurements

	Reverberation Chamber	Small Office	Large Office
Absorption at 512	43,700 units[a]	186,000 units	282,000 units
L (Equation 2) Measured level	66.3 db 64.4 db	60.0 db 61.8 db	58.2 db 59.8 db
Error	+ 1.9 db	— 1.8 db	— 1.6 db

[a]All values in tables are given in centimeter-gram-second units. The common unit for expressing sound absorption units is the Sabine, which is in English units. The units given above are equal to Sabines x 929

Table 2—Noise Level of Desk Fan

Apparatus	Desk Fan. 4 blades—16 in. diameter—over-all height 20 in. Mounted on 24 in. x 36 in. sheet metal panel secured to floor.
Data	Total sound power 21.8 microwatts (hemisphere radius = 24 in.) Significant frequency bands = 100 — 200 Selected mean frequency = 150 cps

Test Room Measurements

	Reverberation Chamber	Small Office	Large Office
Absorption at 150	25,800 units	105,000 units	170,000 units
L (Equation 2) Measured level	69.3 db 69.8 db	63.3 db 63.5 db	61.1 db 60.0 db
Error	— 0.5 db	+ 0.2 db	+ 1.1 db

Table 3—Noise Level of Oil Pump

Apparatus	Oil Pump—gear type, powered by ¼ hp motor—1725 rpm Mounted on three vibration isolators Dimensions (including motor) 20 in. x 12 in. x 8 in. high.
Data	Total sound power = 375 microwatts Significant frequency bands 800-4800 cps Selected mean frequency 2400 cps

Test Room Measurements

	Reverberation Chamber	Small Office	Large Office
Absorption at 2400	110,000 units	210,000 units	302,000 units
L (Equation 2) Measured level	75.3 db 73.5 db	72.5 db 73.0 db	70.9 db 70.4 db
Error	+ 1.8 db	— 0.5 db	+ 0.5 db

absorption of a room will vary considerably with frequency and this factor must be allowed for.

In the tabulated measurements, the frequency analysis was made with a band pass analyzer. The bands listed as significant are those which contain the greatest portion of the energy, and the mean frequency selected was the center of these bands. A more accurate procedure would be to compute the probable level at each band and then sum these with weightings taken from the original analysis. This is, however, a somewhat tedious operation, and it appears that sufficient accuracy is obtained by using a mean frequency value.

It may be that for comparative rating of equipment, a ± 2 db accuracy is not sufficient. However, in determining whether the obtained levels are acceptable or tolerable, such a margin of error is probably permissible, in view of the difficulty of establishing the desirable levels accurately. In this connection, it should be noted that a considerable variation in room absorption produces a relatively small error in the computation. An error of 25 per cent in the absorption-estimate produces only 1 db error in the final result.

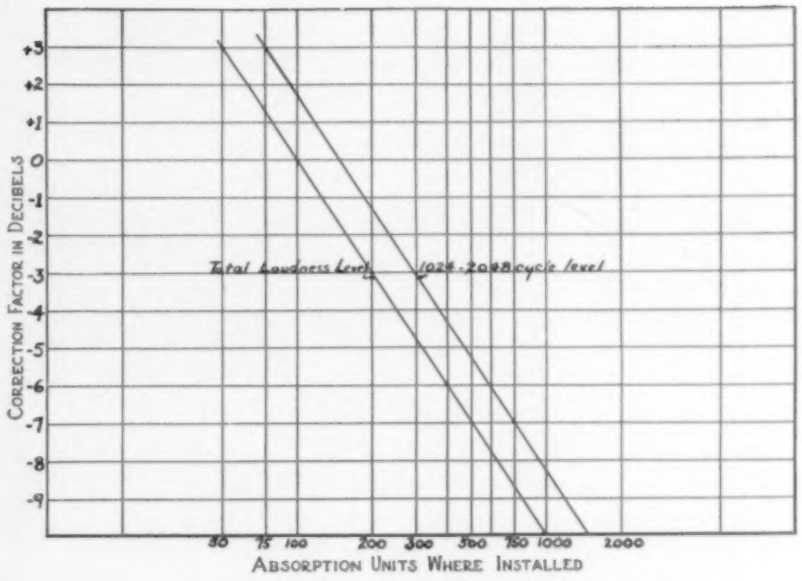


Fig. 1—Correction to be applied to rating in rooms of varying absorbing power

The reading at a distance of 24 in. and an angle of 45 deg from the axis of the fan in the above measurements was 77 db. The average room levels obviously are quite different, varying from 60.0 to 69.8 db. The measurement taken close by penalizes the unit if judged by its numerical value only.

If total sound power seems a desirable basis on which to rate the noise of equipment, single measurements at a fixed point will evidently not suffice. The general instructions for measuring noise levels contained in existing codes are entirely applicable, but additional research work is necessary. It may be possible with a little experience to find a single point which will be representative of the average hemisphere reading, or to apply a constant correction to some such single point reading. It will be necessary, however, in the beginning to make a careful determination of total sound power for each of the apparatus types to be tested. The additional work involved seems well worthwhile in the interests of the designer, installer and producer.

The discussion so far has been devoted to apparatus which is to be located in a conditioned space. For remotely located equipment, as already indicated, other procedures are necessary. Noise radiated into the fan room itself can be rated as described hitherto. A more important figure, however, is the quantity of noise radiated into the duct system. Several methods of arriving at this quantity have been suggested, but more experimental data are needed. In the case of certain types of fans, it has been stated that a measurement taken at the intake would check one made at the exhaust port within one or two decibels. By measuring at the intake, it is possible to avoid the air turbulence at the microphone diaphragm which interferes with readings in the exhaust air stream. This type of procedure will probably be useful in cases where an open intake is available, and where the shape of the intake does not itself produce new sound frequencies.

A laboratory procedure which has been tried with some success requires the use of a probe tube. A small glass or metal tube is attached to the face of the microphone (it must be a pressure type) and inserted into the duct. The tube should be suitably streamlined to avoid noise from air turbulence. The disadvantage of such a procedure is that the microphone has to be recalibrated with the tube in place, but if a simple source of sound energy such as a loud speaker is available, the recalibration presents no great difficulty.

In some laboratory work, the fan or blower has been attached to a short run of straight duct which extends through a soundproof partition. It is assumed that the presence of the duct makes no significant change in the sound output of the fan, and measurements are made of the average level in the room into which the duct exhausts. If the acoustic absorption of this room is known, the power radiated may be computed from the formula given above. Tests have been made by placing the microphone on a line extending at a 45 deg angle from the duct outlet. Readings are made at various distances approaching the duct outlet, until a point is reached where air turbulence interferes. The curves are then extrapolated to give the probable level at the opening itself. Data are lacking on this procedure, and it is open to question because it does not take into account the open end reflections which may take place at the mouth of the duct. Likewise it is not established that such a measurement gives data applicable under other load conditions.

A method used by the author provides for mounting the microphone in a tube or box whose face is flush with the duct wall. The opening into the duct wall is then covered by a layer of silk or similar material. The level thus measured compared favorably with the average across the duct section. Data reported by another laboratory using the same procedure found that the difference is negligible. The one doubtful factor that remains is whether the air, in rustling the silk cover, produces some extraneous noise.

It is significant that studies are being made of the noise generated in the duct system itself, as well as the attenuations introduced in the duct system, at Rensselaer Polytechnic Institute under a cooperative agreement sponsored by the ASHVE.

Several papers have been presented to the Society since 1930 on outlet grille measurements, where the rather common procedure of taking a single measurement at a short distance from the grille on a 45 deg angle was followed. While excellent for comparative purposes it does not supply as much data as could be desired. The author recently participated in a study where the total noise radiated was determined from the average level set up in a room of known acoustic properties. A duct system was designed with a very low background noise level, so that any noise created by the units could be readily identified. The data thus obtained were then charted to indicate the level which would be expected under any acoustic conditions.

The type of conversion chart used is shown in Fig. 1. The absorption of the test room for the over-all noise was roughly 100 sabines, and for the 1024-2048 cycle band, which was considered representative of the high frequency range, was 150 sabines. The ordinates give the number of decibels which must be added or subtracted from the level measured in the original test room to arrive at the new levels which would occur in rooms of varying acoustical properties.

Referring again to the formulae previously given, it will be seen that if the average level L_0 is known for any given room with known absorbing power, the new level L_1 in a different room will be given by the expression:

$$L_1 = L_0 - 10 \log_{10} \left(\frac{\Sigma a_1 s_1}{\Sigma a_0 s_0} \right)$$

Summary

The principal objectives for a desirable test code have been briefly outlined. The nature of the differences of opinion as regard methods of expressing results have been discussed. With respect to unitary apparatus, the chief question is whether a single comparative method of rating is adequate, or whether an attempt should be made to measure total sound power in order to provide data for prediction of noise levels. The additional operations necessary for this purpose have been given, with some data on actual apparatus.

Several available methods of measuring the noise radiated into duct systems have been discussed and one practical method of measuring outlet noise has also been described.

There is a definite need for further research and the cooperation of Society members and others in supplying information on the subject is essential for a complete solution of the noise problem in the field of heating, ventilating and air conditioning.

Census of Engineers in Construction Field

Mobilization of the engineering and architectural professions for national defense is now under way with the preparation by their professional organizations of a nationwide census of 115,000 engineers and architects skilled in the design and supervision of all types of construction needed in case of national emergency, according to a joint statement made June 10 by John P. Hogan, President, *American Society of Civil Engineers*, and Stephen F. Voorhees, representing the *American Institute of Architects*.

The listing of 15,000 architects at the home of the *American Institute of Architects*, The Octagon, Washington, D. C., and of 100,000 engineers at the headquarters of the *American Society of Civil Engineers*, 33 West 39th Street, New York City, will be carried out in three steps. Each man or office will be classified as to skill in the design and supervision of construction of airports with the necessary drainage, runways, hangars, administration buildings, and housing facilities; in water supply and purification plants; in sewage and industrial-waste disposal systems, roads, and tunnels; in the enlargement of industrial plants with the necessary housing facilities for workmen, water, and disposal systems; in port developments with loading wharves, docks, warehouses, and railroads; and in cantonments with barracks, including water, sewage, heating, lighting, and other systems, and with the necessary mechanical, refrigerating, heating, and ventilating accessories.

Cooperating with the *American Society of Civil Engineers* and the *American Institute of Architects* in this national movement are the following engineering organizations and their presidents: *American Institute of Mining and Metallurgical Engineers*, H. G. Moulton, New York; *American Society of Mechanical Engineers*, Warren H. McBryde, San Francisco; *American Institute of Electrical Engineers*, F. Malcolm Farmer, New York; *American Institute of Chemical Engineers*, Webster N. Jones, Pittsburgh; *American Institute of Consulting Engineers*, Philip W. Henry, New York; American Society of Heating and Ventilating Engineers, Frederick E. Giesecke, College Station, Texas; *American Society of Military Engineers*, Brigadier General G. B. Pillsbury, Ross, Calif.; *American Society of Refrigerating Engineers*, George E. Hulse, New Haven, Conn.; and the *National Society of Professional Engineers*, John C. Riedel, New York.

The first step of the census, just started, is the listing of engineering and architectural firms, partnerships, and individuals in private practice. This is being accomplished by the cooperating national engineering and architectural organizations through special committees in each of their local sections and chapters, which are located in almost every city of the nation and, thus, in a position to provide nearly 100 per cent coverage. The second step will consist in indexing and classifying each firm or individual according to qualifications so as to permit of ready selection of those best fitted to undertake in any part of the country whatever type of construction would be necessary in the interests of national defense. The final step will be similar to the first two in all details except that, instead of firms, there will be listed and classified architects, engineers, draftsmen, surveyors, and specialists, who may be available to work with firms assigned jobs to design and supervise.

In these preparations every effort will be made to avoid the dislocation of those engineers or architects now engaged in industry, in the utilities, in governmental and in other services, which might be expanded in any necessity in case of national emergency.

HOUSTON INVITES YOU

The Fall Meeting of the Society will be held in Houston, Texas, October 14-15, at the Rice Hotel. All members are cordially invited by the South Texas Chapter.

KANSAS CITY IN JANUARY

The 47th Annual Meeting will be held in Kansas City, Mo., January 27-29, 1941. Mark the dates and plan to join your fellow members at the Hotel Muehlebach.

Pittsburgh Experiment Station of the U. S. Bureau of Mines where the Research Laboratory of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS is located

Summer Cooling Load as Affected by Heat Gain Through Dry, Sprinkled and Water Covered Roofs

By F. C. Houghten,* (*MEMBER*), H. T. Olson,** and Carl Gutberlet***
Pittsburgh, Pa.

AS part of the general research project of determining the cooling load for summer cooling and air conditioning, the 18 ft x 18 ft x 8 ft high cubicle shown in Figs. 1 and 2 was built by the ASHVE Research Laboratory during the spring of 1939. It was located on the roof of the Warehouse Building of the Pittsburgh Experiment Station of the U. S. Bureau of Mines, where it was exposed to full solar radiation from shortly after sunrise until just before sunset. The cubicle was built as a part of the program of the Technical Advisory Committee on Cooling Load in Summer Air Conditioning, consisting of C. M. Ashley, *Chairman,* John Everetts, Jr., M. G. Kershaw, A. E. Knapp, C. S. Leopold, L. S. Morse, R. M. Stikeleather, and J. H. Walker. This Committee is interested in heat gain through various types and orientation of building constructions, as affected by both the resistance to heat flow and heat capacity of the structures.

The test building walls included four 5½ ft wide x 7 ft high wall sections of 13 in. brick and plaster, and four of 4 in. brick, 8 in. hollow tile and plaster, each type of construction having north, east, south, and west exposures; also, three similarly sized panels of 4 in. brick veneer on frame construction consisting of wood sheathing, 2 in. x 4 in. studding, metal lath and plaster, with east, south and west exposures.

The deck of the horizontal roof of the test cubicle was divided into 5-ft square panels, consisting of one 4-in. gypsum, one 2-in. gypsum, one 4-in. tile, one 6-in. concrete, three 2-in. concrete, and two 2-in. yellow pine plank constructions, all covered with tarred felt and coal tar pitch roofing. One each of the 2-in. concrete and 2-in. pine panels were built so that the roofing over them could be either sprinkled or flooded with up to 6 in. of water. With one exception the built-up roofing was covered with approximately ½ in. of slag; this exception being the third 2-in. concrete panel which was left with a smooth asphalt finish during part of the summer and later with painted aluminum.

This paper deals with variations in the heat flow through a roof as affected by the surface finish and by sprinkling or flooding during the summer heat when the space below is cooled and air conditioned.

The inside of the cubicle was summer cooled and air conditioned to 75 F and 50 per cent relative humidity throughout the study. A Nicholls heat flow meter was attached to the inside center of each of the side wall and roof panels in order to give an hourly measurement of the rate of heat flow through their inside surfaces. Thermocouples gave the outside air temperature, the outside surface temperatures, the inside surface tem-

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**Research Engineer, ASHVE Research Laboratory.
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Presented at the Semi-Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Washington, D. C., June, 1940.

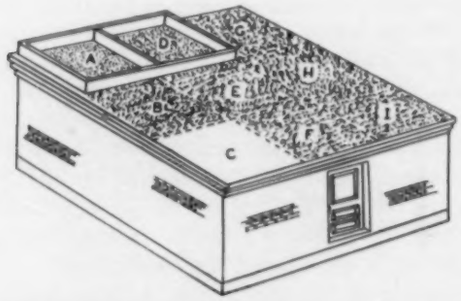
Fig. 1—Test cubicle located on roof of Warehouse Bldg. of the Pittsburgh Experiment Station, U. S. Bureau of Mines

Fig. 3—Interior of test cubicle showing means used for measuring heat flow through interior surface and measuring temperatures

peratures, and the inside air temperature 6 in. from the center of the panels, and, with the flooded roofs, the temperature of the water at different depths from the surface. Additional thermocouples gave the temperature part-way through some of the types of construction. The means for measuring the heat flow through the inside surface and for observing temperatures is shown in Fig. 3.

Figs. 4 to 8 give curves for heat flow through the inside surface, and temperatures through the roof panels from the air 6 in. below the inside surface to the air 6 in. above the outside surface throughout a 24-hour period, for the 2-in. concrete construction flooded with 6 in. of water, the 2-in. pine construction flooded with 6 in. of water, the 2-in. concrete with dry, smooth asphalt finish, respectively, all for the same day, August 30, 1939. Fig. 8 also shows the solar radiation intensity and wind velocity for August 30.

The heat flow through the concrete panel with the dry slag finish for August 30 and September 8 is given in Fig. 9, together with that through the 2-in. concrete panel covered with 6 in. of water for August 30, and through the concrete with the top surface damp or



A-2" CONCRETE DOUBLE SLAG WATER COOLED PANEL
B-2" DRY SLAG CONCRETE PANEL
C-2" CONCRETE SMOOTH FLAT ASPHALT
D-2" PLANK DOUBLE SLAG WATER COOLED PANEL
E-2" DRY SLAG PLANK PANEL
F-4" DRY SLAG TILE PANEL
G-2" DRY SLAG GYPSUM PANEL
H-4" DRY SLAG GYPSUM PANEL
I-6" DRY SLAG CONCRETE PANEL

Fig. 2—Sketch of test house showing location of roof panels

sprinkled for September 8. Similar heat flows for the 2-in. plank with the same top surface conditions are given at the top of the chart. The solar radiation, outside dry-bulb and wet-bulb temperatures are also given for the two days as well as the wind velocity for September 8.

The heat flows through the 2-in. concrete panel with the dry slag finish for September 2 and September 8, through the concrete panel with the damp surface for September 8, and through the concrete flooded with 1 in. of water for September 2 are given in Fig. 10. Similar heat flows for the 2-in. pine panel with like surface conditions are given at the top of the chart, while the solar radiation, outside dry-bulb and wet-bulb temperatures for the two days are also given together with the wind velocity for September 2.

The heat flow through the 2-in. concrete panel with the smooth asphalt finish on September 8 is given in Fig. 11, as well as those through the dry slag finish on September 8 and September 15, and through the smooth asphalt finish painted aluminum for September 15. At the center of the chart are shown the outside dry and wet bulb temperatures for the two dates, the top surface temperatures of the smooth asphalt finish concrete panel, and the temperatures for this same panel painted with both a varnish base aluminum paint, and with a bituminous aluminum paint, for Sept. 15. The solar radiation is given at the top of the chart for September 8 and 15 and the wind velocity is given for September 15.

The curves in Figs. 4, 5, 6 and 7, and the curve for the concrete panel with the smooth asphalt surface for August 30 in Fig. 8 give a direct comparison between the heat flow through the 2-in. concrete panel with 6 in. of water, with a dry slag surface, and with a smooth asphalt finish; also for the 2-in. plank panel with 6 in. of water and the dry slag surface.

The curves in Figs. 8, 9, 10 and 11 give comparisons of the heat flows through the concrete panel with the smooth black and smooth aluminum painted asphalt surface, with the dry slag surface, with 6 in. of water, with 1 in. of water, and with damp slag; also for the 2-in. plank panel with dry slag surface, with 6 in. of water,

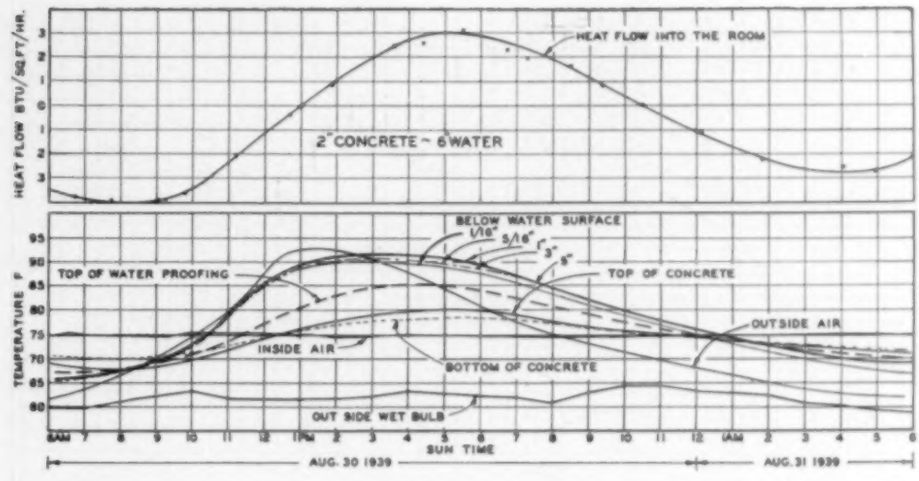


Fig. 4—Relation between time and heat flow through inside surface of 2-in. concrete panel flooded with 6 in. of water and temperatures of water and other points through roof

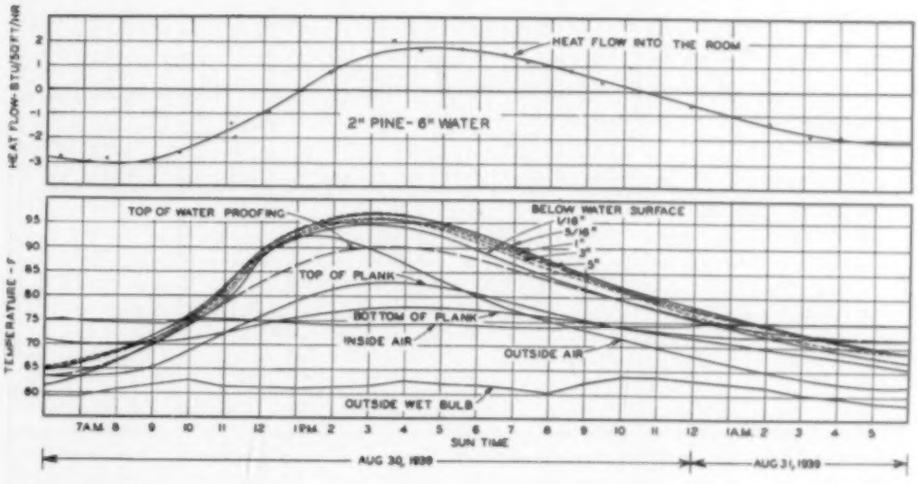


Fig. 5—Relation between time and heat flow through inside surface of 2-in. pine panel flooded with 6 in. of water and temperatures of water and other points through roof

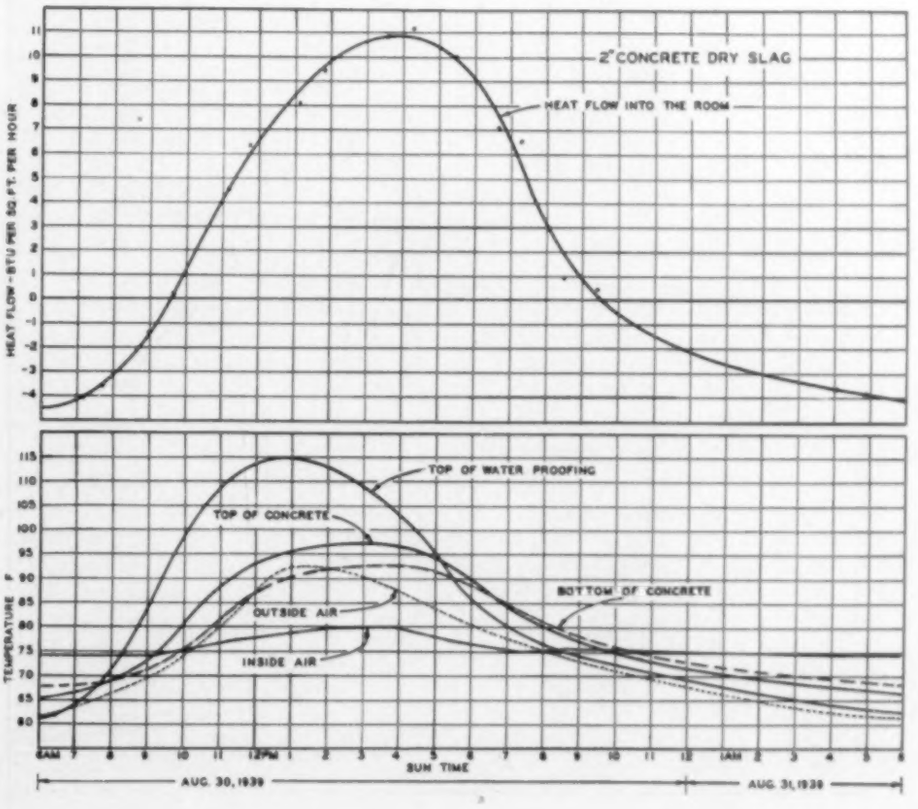


Fig. 6—Relation between time and heat flow through inside surface of 2-in. concrete panel and temperatures near and through panel

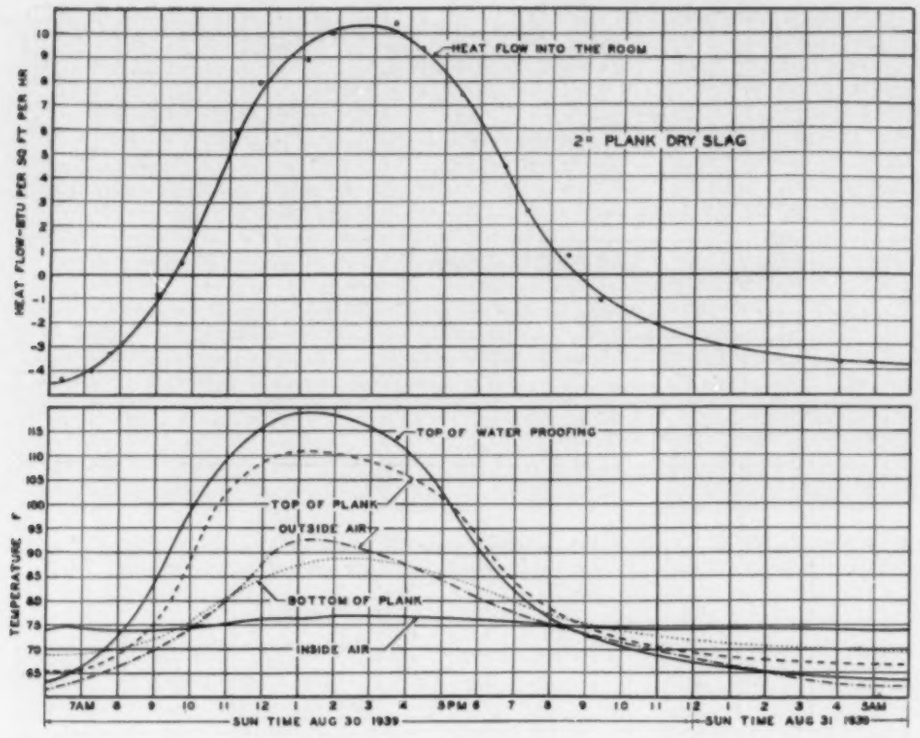

HEAT FLOW INTO THE ROOM
2" PLANK DRY SLAG
HEAT FLOW-BTU PER SQ FT PER HR
TOP OF WATER PROOFING
TOP OF PLANK
OUTSIDE AIR
BOTTOM OF PLANK
INSIDE AIR
TEMPERATURE F
7AM 8 9 10 11 12 1 2 3 4 5PM 6 7 8 9 10 11 12 1 2 3 4 5AM
SUN TIME AUG 30 1939
SUN TIME AUG 31 1939

Fig. 7—Relation between time and heat flow through inside surface of 2-in. dry slag pine panel and temperatures near and through panel

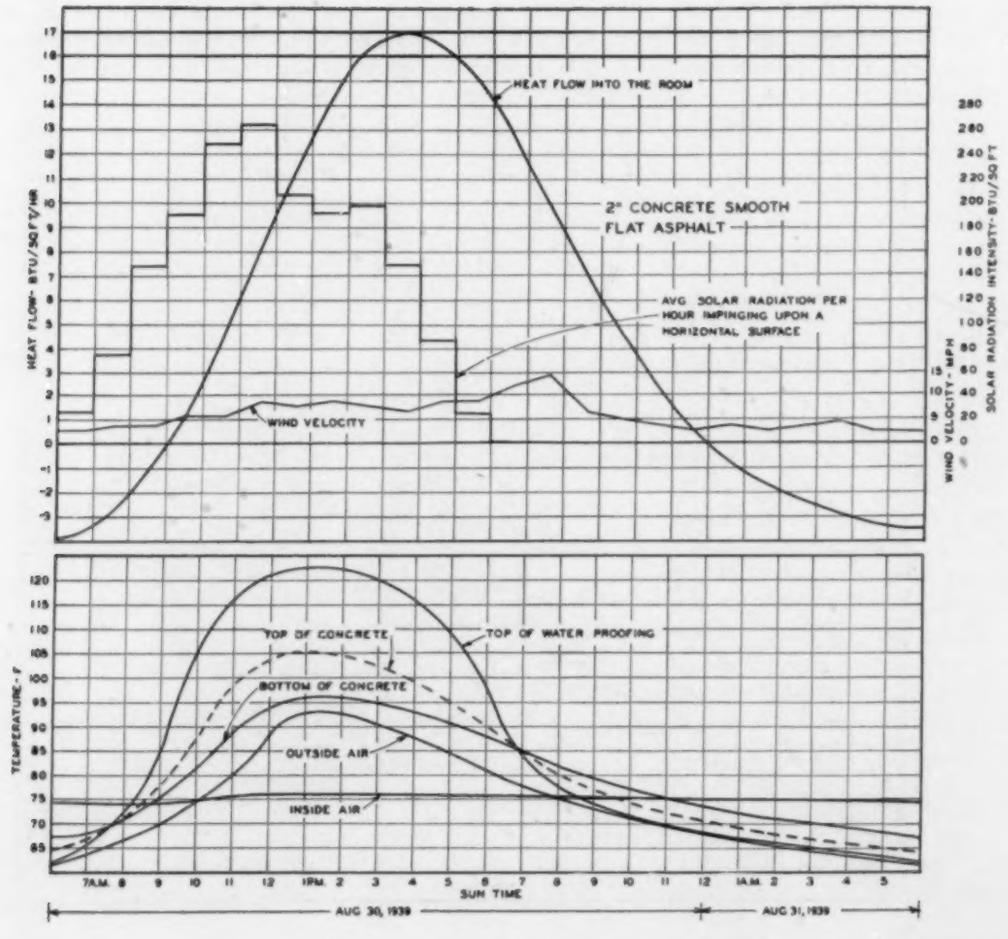

HEAT FLOW INTO THE ROOM
2" CONCRETE SMOOTH FLAT ASPHALT
AVG SOLAR RADIATION PER HOUR IMPINGING UPON A HORIZONTAL SURFACE
WIND VELOCITY
HEAT FLOW- BTU/SQFT/HR
WIND VELOCITY-MPH
SOLAR RADIATION INTENSITY-BTU/SQ FT
TOP OF CONCRETE
TOP OF WATER PROOFING
BOTTOM OF CONCRETE
OUTSIDE AIR
INSIDE AIR
TEMPERATURE-F
7A.M. 8 9 10 11 12 1P.M. 2 3 4 5 6 7 8 9 10 11 12 1A.M. 2 3 4 5
SUN TIME
AUG 30, 1939
AUG 31, 1939

Fig. 8 — Relation between time and heat flow through inside surface of 2-in. concrete panel with smooth asphalt finish, also relation between time and solar radiation impinging upon roof

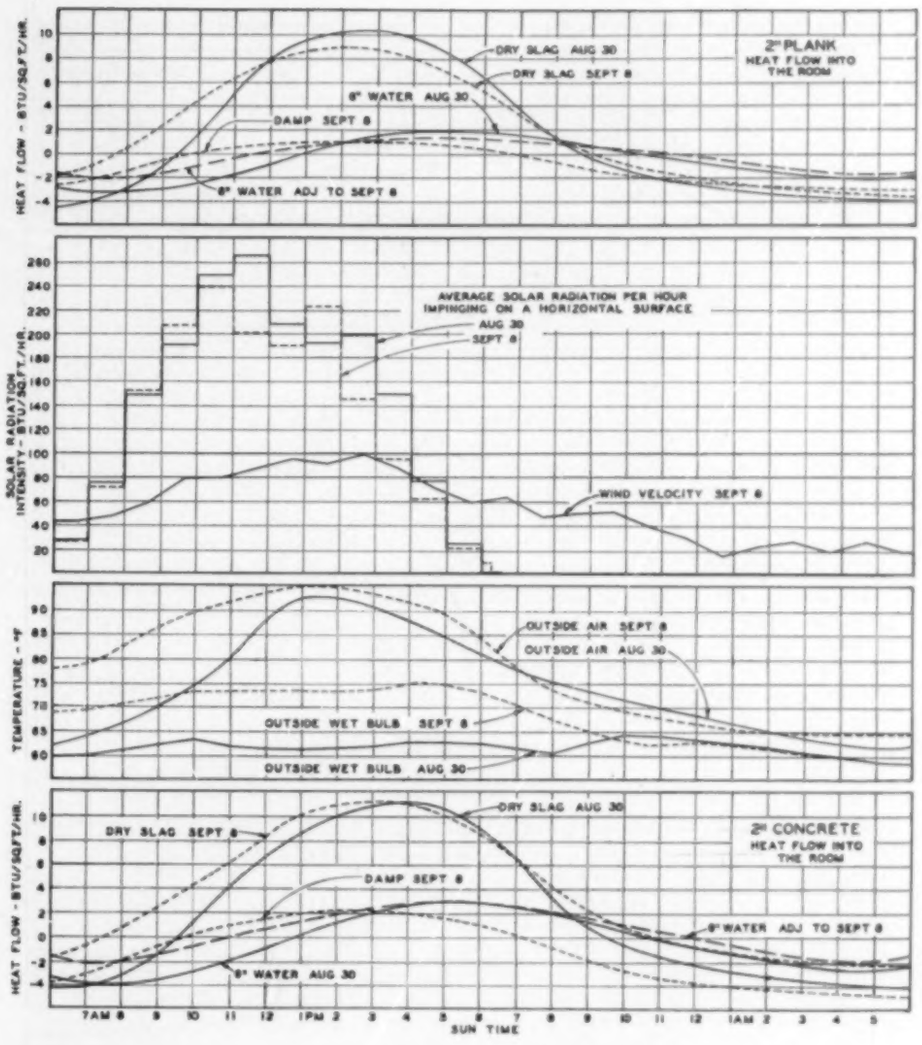

2" PLANK
HEAT FLOW INTO THE ROOM
DRY SLAG AUG 30
DRY SLAG SEPT 8
6" WATER AUG 30
DAMP SEPT 8
6" WATER ADJ TO SEPT 8
HEAT FLOW - BTU/SQ.FT./HR.
AVERAGE SOLAR RADIATION PER HOUR IMPINGING ON A HORIZONTAL SURFACE
AUG 30
SEPT 8
WIND VELOCITY SEPT 8
SOLAR RADIATION INTENSITY - BTU/SQ.FT./HR.
OUTSIDE AIR SEPT 8
OUTSIDE AIR AUG 30
OUTSIDE WET BULB SEPT 8
OUTSIDE WET BULB AUG 30
TEMPERATURE - °F
DRY SLAG AUG 30
DRY SLAG SEPT 8
2" CONCRETE
HEAT FLOW INTO THE ROOM
DAMP SEPT 8
6" WATER ADJ TO SEPT 8
6" WATER AUG 30
HEAT FLOW - BTU/SQ.FT./HR.
7AM 8 9 10 11 12 1PM 2 3 4 5 6 7 8 9 10 11 12 1AM 2 3 4 5
SUN TIME

Fig. 9—Relation between time and heat flow through inside surface of 2-in. concrete panel and 2-in. pine panel dry, flooded with 6 in. of water and damp; also for the 6 in. of water adjusted to Sept. 8. The solar radiation impinging upon roof and wet- and dry-bulb temperatures are also given

with 1 in. of water and with damp slag, for different days.

The fact that only one concrete and one pine panel were available for 6 in. and 1 in. flooding and for sprinkling made it impossible to obtain a direct comparison between these different conditions on the same day. An attempt is made in Fig. 9 to adjust the data for the 6-in. flooded panel from August 30 to September 8; in Fig. 10 to adjust the data for 1-in. flooded panel from September 2 to September 8; and in Fig. 11 to adjust the data for the smooth aluminum-painted asphalt surface from September 15 to September 8. This is done by plotting in each case the heat flow through the dry slag covered panels for the two days in question and by assuming that approximately the same percentage change would occur in the heat flow through the panel in question which was tested on only one of these two days. As a result of this assumption, heat flow curves through all of these panels are plotted as adjusted to a single day, September 8. While there is not sufficient background to place complete confidence in this adjustment the two facts,—*first*, that some adjustment in this direction must naturally apply, and *second*, that the adjustment between the two days is never great, should lend considerable confidence to the comparison.

The series of heat flow curves given in Fig. 12 as reproduced from the charts, Figs. 4 to 11, gives a direct comparison between the heat flow through the different panels with different surface conditions as observed for, or adjusted to, September 8. The same series of heat flow curves, adjusted to September 8, and given in Fig. 12 are repeated in Fig. 13, adjusted to what has been assumed to be the design outside dry-bulb temperature and the design solar radiation intensity on a horizontal surface for August 1.

It is of interest to note the considerable reduction in heat flow through either the damp or flooded concrete roofs below that given for the same roofs with dry slag or with smooth asphalt without and with aluminum painted surfaces. Approximately the same relationship is shown for the 2-in. pine panel; however, all of the heat flow values are somewhat smaller for the wood panels than for the concrete panels. A comparison of the 6-in. flooded, the 1-in. flooded, and the damp roofs all corrected for the same day, September 8, in Figs. 8 and 9, shows maximum heat flows of 2.8, 4.7, and 2.1 Btu per square foot per hour, respectively. Of greater interest, however, is the fact that these reductions are from a value of approximately 11 Btu per square foot per hour for the dry roof of the same construction, with the exception that the water proofing membrane on the damp and flooded roof was a little thicker as shown in the description, Fig. 14.

The effect of water in either the case of the sprinkled

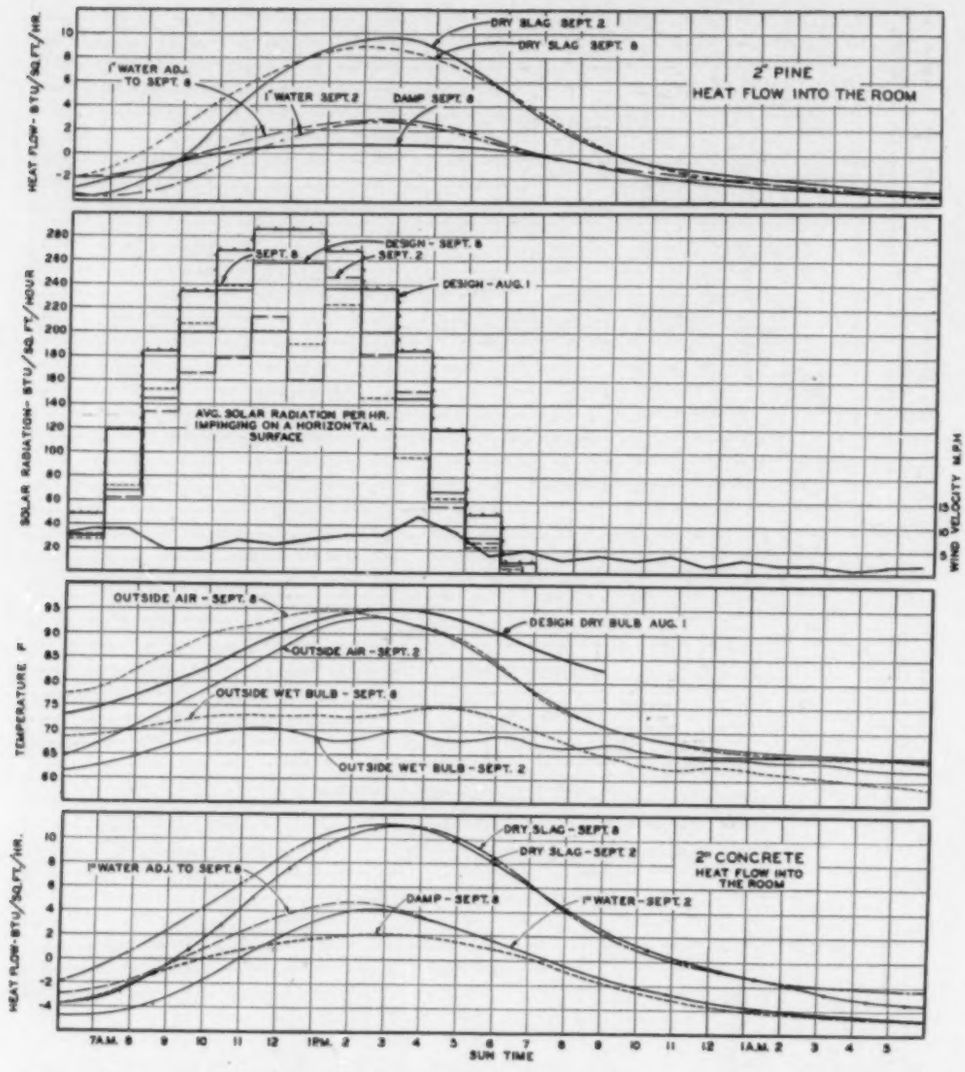

HEAT FLOW - BTU/SQ.FT./HR.
DRY SLAG SEPT. 2
DRY SLAG SEPT. 8
1" WATER ADJ. TO SEPT. 8
1" WATER SEPT. 2
DAMP SEPT. 8
2" PINE
HEAT FLOW INTO THE ROOM
SOLAR RADIATION - BTU/SQ. FT./HOUR
SEPT. 8
DESIGN - SEPT. 8
SEPT. 2
DESIGN - AUG. 1
AVG. SOLAR RADIATION PER HR. IMPINGING ON A HORIZONTAL SURFACE
WIND VELOCITY M.P.H.
TEMPERATURE F
OUTSIDE AIR - SEPT. 8
DESIGN DRY BULB AUG. 1
OUTSIDE AIR - SEPT. 2
OUTSIDE WET BULB - SEPT. 8
OUTSIDE WET BULB - SEPT. 2
HEAT FLOW - BTU/SQ.FT./HR.
DRY SLAG - SEPT. 8
DRY SLAG - SEPT. 2
2" CONCRETE
HEAT FLOW INTO THE ROOM
1" WATER ADJ. TO SEPT. 8
DAMP - SEPT. 8
1" WATER - SEPT. 2
7 A.M. 8 9 10 11 12 1 P.M. 2 3 4 5 6 7 8 9 10 11 12 1 A.M. 2 3 4 5
SUN TIME

Fig. 10—Relation between time and heat flow through inside surface of 2-in. concrete panel and 2-in. plank panel, dry, flooded with 1 in. water and damp; also for 1 in. of water adjusted to Sept. 8. The solar radiation impinging upon the roof for Sept. 2 and 8, the design solar radiation for Aug. 1 and Sept. 8, the design outside temperature for a 95 F day and dry- and wet-bulb temperature for Sept. 2 and 8 are also given

or of the flooded roof is to greatly reduce the rate of heat flow from that found for the same panels in dry condition. Of greater interest, however, is the effect of the water to absorb a large part of the radiant heat, to retain it with a uniform temperature throughout the water depth, and to dissipate it back to the air through the latent heat of evaporation. It will be seen that during maximum temperature conditions the total temperature variation through the depth of the water never exceeds 4 deg and that this temperature spread is usually considerably less. There is also interest in the fact that during the time that solar radiation is effective the lowest temperature is found 1/16 in., or immediately below the top surface of the water. This obviously results from the lowering of the top surface temperature by evaporation while a considerable part of the radiant energy is transformed into heat through the depth of water with a somewhat elevated water temperature at the 5 in. depth above that found at other points. The elevation of the temperature at the bottom of the water obviously must result from greater absorption of solar radiation at the level of the top surface of slag.

The comparison between flooding with 6 in. of water and just maintaining the slag damp, Fig. 9, shows that the 6 in. depth of water serves to reduce the rate of heat flow through the panel during the early part of the day and to effect a somewhat greater rate of heat flow thereafter. This is obviously due to the lag in the rise in water temperature during the early part of the day and the lag in the drop in this same temperature during the latter part of the day and the night due to the heat capacity of the water. The one inch of water, having a lower heat capacity, warms up more rapidly, gives a higher maximum rate of heat flow earlier in the day than is the case for the 6-in. flooded roof.

The fact that the aluminum painted surface considerably reduces the heat flow through an otherwise black roof is amply demonstrated in earlier Laboratory publications.[1, 2] This is again brought out in Fig. 11 for the 2-in. concrete with a smooth asphalt finish, without and with aluminum paint. This comparison indicates a maximum rate of heat flow through the aluminum painted, smooth asphalt panel of 10.3 Btu per square foot per hour on September 8. This surface was painted with a varnish base aluminum paint. On the same day a very small section of the same panel was covered near the edge where it would not affect the heat flow meter reading, with a tar base aluminum paint giving the difference in surface temperature indicated in the center of Fig. 11. It will be noted that the varnish base aluminum gave a reduction in the top surface temperature, and therefore in the heat flow, below that given for the bituminous aluminum paint. No heat flow rates were determined for the bituminous aluminum painted surface.

As compared with the maxium heat flow rate of 11.2 Btu per square foot per hour for the dry slag covered roof on September 8, Figs. 9 and 10, the black asphalt finish roof on the same day gave a maximum heat flow rate of 16.2 Btu per square foot per hour. It should be pointed out, however, that in the case of the slag covered roof the slag pebbles were placed on the tar pitch

[1]Absorption of Solar Radiation in Its Relation to the Temperature, Color, Angle and Other Characteristics of the Absorbing Surface, by F. C. Houghten and Carl Gutberlet. (ASHVE Transactions, Vol. 36, 1930, p. 137.)

[2]Symposium on Thermal Insulating Materials, March 8, 1939. (*American Society for Testing Materials*, Phila., Pa.).

giving additional thickness and heat capacity, so that the indicated difference in heat flow represents the combined effect of the difference in color and thickness of the slag roof. The cross-sections of these roofs are shown in the sketches, Fig. 14.

It is of interest to note the considerable drop in temperature, indicating resistance to heat flow, through the water proofing consisting of several layers of felt and tar pitch as indicated in the sketch, Fig. 13. Thus, at the time of maximum heat flow the temperature drop through the water proofing was 5, 7½, 7 and 7½ deg for the flooded concrete, dry concrete, flooded pine, and dry pine, compared with temperature drops of 1½, 4½, 3½ and 21 deg through the concrete and pine in these respective panels.

There is also plotted in Fig. 10 what has heretofore been used by the Laboratory[6] as an August 1 design solar radiation day. Although the solar radiation on a horizontal surface is greater on June 21, the combined effect of high air temperature and high solar radiation is assumed to be greatest on August 1. There is also plotted what has been assumed by the Laboratory to be a design outside temperature curve for a 95 F day on August 1. It will be observed that September 8, 1939 was low for a design solar radiation day, but not far from right for a design outside 95 F temperature day. Actually the air temperature reached 95 F at about one o'clock on September 8; during the morning the temperature was higher and during the afternoon it was lower than a typical 95 F day on August 1.

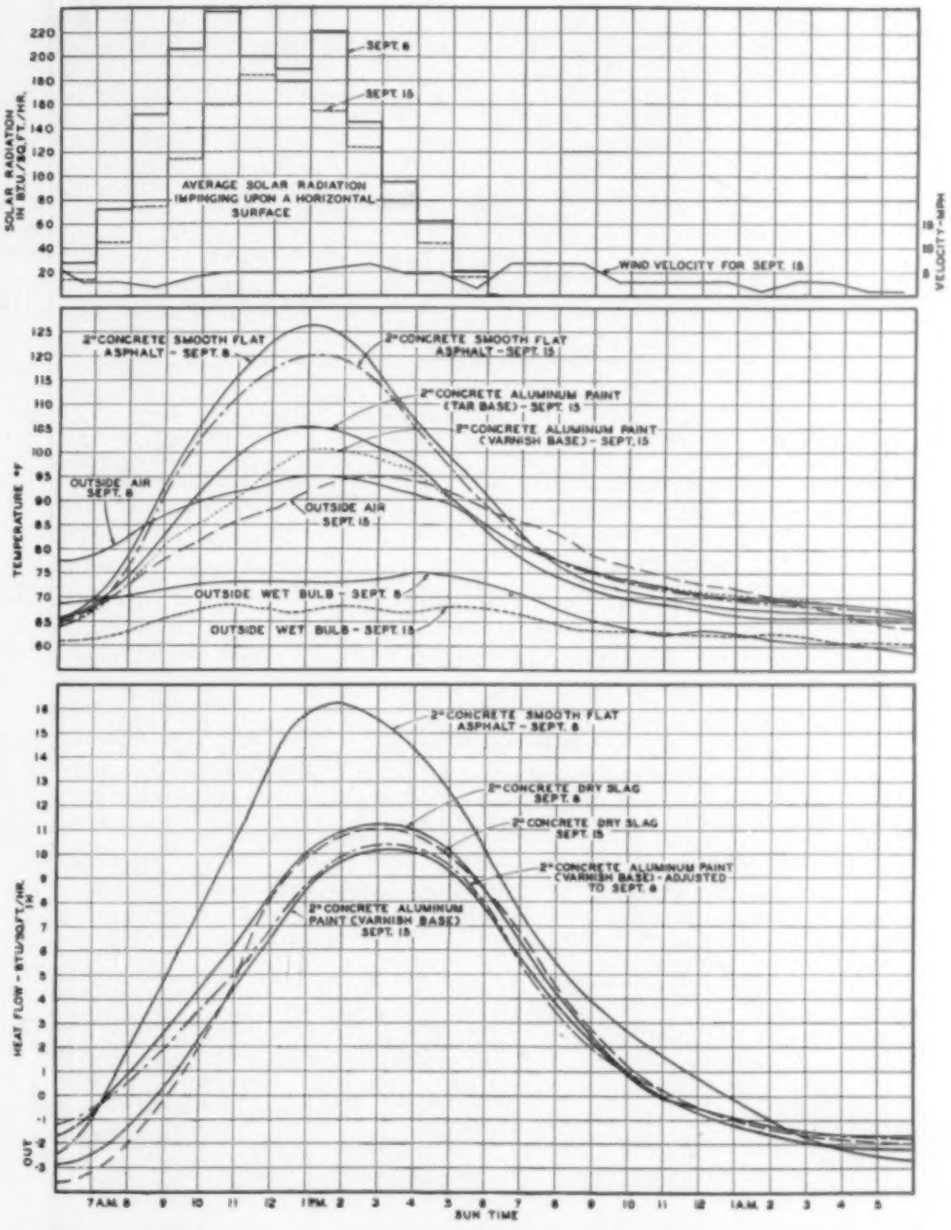

SOLAR RADIATION IN BTU/SQ.FT./HR.
SEPT. 8
SEPT. 15
AVERAGE SOLAR RADIATION IMPINGING UPON A HORIZONTAL SURFACE
WIND VELOCITY FOR SEPT. 15
VELOCITY-MPH
TEMPERATURE °F
2" CONCRETE SMOOTH FLAT ASPHALT - SEPT. 8
2" CONCRETE SMOOTH FLAT ASPHALT - SEPT. 15
2" CONCRETE ALUMINUM PAINT (TAR BASE) - SEPT. 15
2" CONCRETE ALUMINUM PAINT (VARNISH BASE) - SEPT. 15
OUTSIDE AIR SEPT. 8
OUTSIDE AIR SEPT. 15
OUTSIDE WET BULB - SEPT. 8
OUTSIDE WET BULB - SEPT. 15
HEAT FLOW - BTU/SQ.FT./HR. IN
OUT
2" CONCRETE SMOOTH FLAT ASPHALT - SEPT. 8
2" CONCRETE DRY SLAG SEPT. 8
2" CONCRETE DRY SLAG SEPT. 15
2" CONCRETE ALUMINUM PAINT (VARNISH BASE) - ADJUSTED TO SEPT. 8
2" CONCRETE ALUMINUM PAINT (VARNISH BASE) SEPT. 15
7 A.M. 8 9 10 11 12 1 P.M. 2 3 4 5 6 7 8 9 10 11 12 1 A.M. 2 3 4 5
SUN TIME

Fig. 11—Relation between time and heat flow through inside surface of slag concrete panel for Sept. 8 and 15, the 2-in. concrete panel with smooth black tar pitch finish for Sept. 8 and the 2-in. concrete black top panel painted aluminum for Sept. 15 and adjusted to Sept. 8. The solar radiation impinging upon room for Sept. 8 and Sept. 15, the surface temperatures and dry- and wet-bulb temperatures for Sept. 8 and 15 are also given

The curves in Fig. 12 may be used for comparative purposes in considering the relative effectiveness of the various roof constructions and surface effects. The adjustment involved in correcting the curves proposed for design purposes in Fig. 13 from the various test days between August 30 and September 15 to design conditions of dry-bulb and solar radiation on August 1 was greater than was the case for Fig. 12. The maximum outside dry-bulb temperatures on August 30, September 2, 8 and 15 were 92.6, 93.3, 94.5, and 95.0 F, respectively, while the maximum solar radiation intensity on a horizontal surface on these same days was 265, 246, 239 and 185 Btu per square foot per hour. The maximum design outside dry-bulb temperature for August 1 should be 95 F, while the maximum design solar intensity on a horizontal surface assumed for this date is 285 Btu per square foot per hour. It will be seen that practically design temperature conditions were realized on September 8 and 15, with but slightly lower temperatures on the other two days. The solar radiation intensity on the test days was always lower than design for August 1. This should naturally be the case since the solar radiation intensity on a horizontal surface is falling off rapidly dur-

[6]Heat Gain Through Glass Blocks by Solar Radiation and Transmittance. by F. C. Houghten, David Shore, H. T. Olson, and Burt Gunst. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, April, 1940, p. 264-270.)

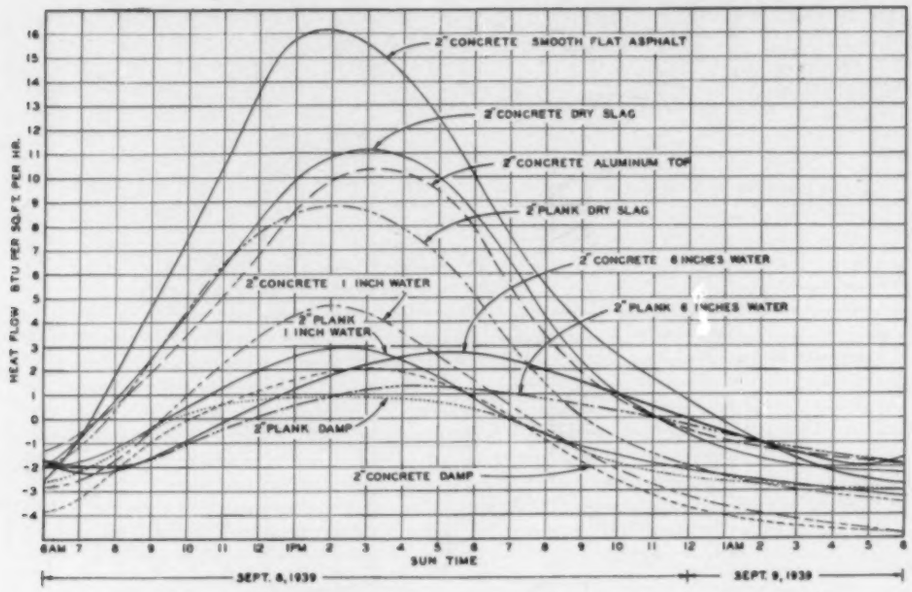

2" CONCRETE SMOOTH FLAT ASPHALT
2" CONCRETE DRY SLAG
2" CONCRETE ALUMINUM TOP
2" PLANK DRY SLAG
2" CONCRETE 6 INCHES WATER
2" CONCRETE 1 INCH WATER
2" PLANK 6 INCHES WATER
2" PLANK 1 INCH WATER
2" PLANK DAMP
2" CONCRETE DAMP
HEAT FLOW BTU PER SQ FT PER HR.
SUN TIME
SEPT. 8, 1939
SEPT. 9, 1939

Fig. 12—Relation between time and heat flow through inside surface of several horizontal roofs studied, all determined for or adjusted to Sept. 8

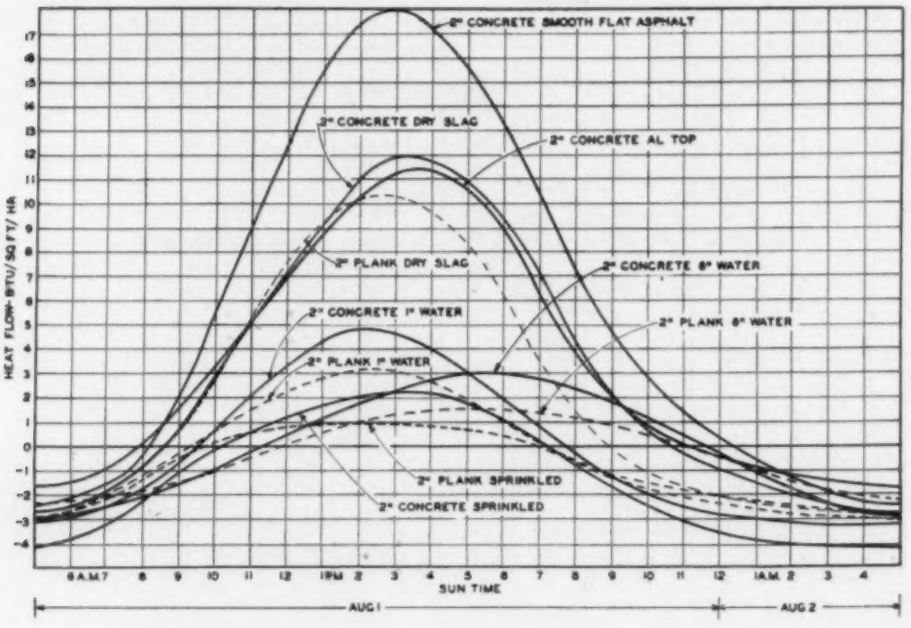


Fig. 13—Relation between time and heat flow through inside surfaces of several horizontal roofs studied, corrected to design day, Aug. 1

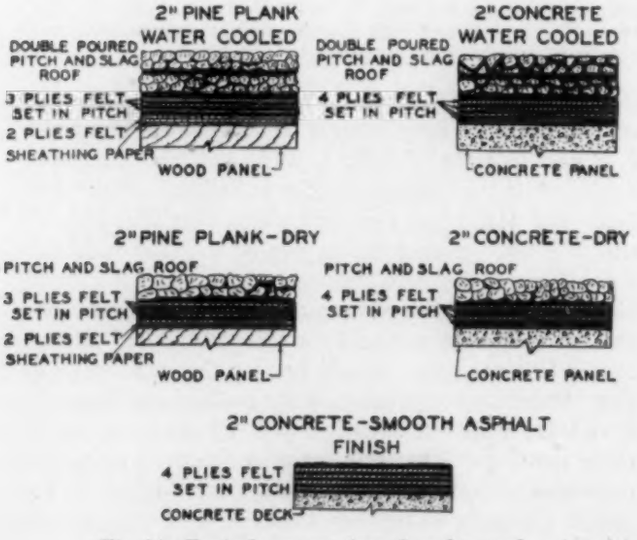


Fig. 14—Typical construction of roofs tested

ing August and September; it being maximum on June 21 and decreasing from that date to a minimum on December 21. Hence, while the adjustment from the other three test dates to September 8 on account of solar radiation was not very great, the adjustment from the test dates to August 1 was considerably larger.

However, a comparison of the location and magnitude of the crest for the different curves in Figs. 12 and 13 indicates that the adjustment to August 1 was never very large. Since there obviously must be some adjustment in the direction indicated, and since there was a fair basis for the assumption used in making this adjustment, it is believed that the curves in Fig. 13 are not greatly in error and that they can therefore be used with considerable confidence until additional work, which is proposed to be carried on in the same cubicle in the near future, makes available more satisfactory design data.

Transverse Heat Conductivity of Wood

By Frederick F. Wangaard*, Seattle, Wash.

DESPITE the general application of wood to purposes which require a substance of considerable thermal resistance, the literature is meager in its supply of conductivity data for any considerable number of timber species, and often the data on these woods have been insufficient to permit a critical comparison of results. Variability in the findings of different workers has led to some confusion as to which results are the more reliable, and in consequence many of the values for the heat conductivity of specific woods, as listed in current handbooks, are open to question.

Moisture content and specific gravity[1, 2, 3] have been recognized as exerting a considerable influence upon the transmission of heat through wood but it is desirable that more data on additional species, compiled by accurate methods, be made available for comparison. This investigation has been undertaken for these reasons.

The purpose of this investigation has been to ascertain the relationships which may exist between the heat conductivity of wood in general and the various influences affecting this property rather than to study a large number of tree-species. Such an approach formulates the basic relationships applicable to all woods and, at the same time, permits an evaluation of those influences which characterize the wood of any given species.

Testing Apparatus

In all essential features the hot-plate apparatus employed at the beginning of the tests corresponded to that recommended as a standard for testing insulating materials by the United States Bureau of Standards.[4]

After the completion of the first series of determinations, it became apparent that the testing of specimens having dimensions less than 12 in. square would be advantageous for a number of reasons: (*a*) moisture conditioning would be facilitated: (*b*) smaller specimens could be so selected that greater uniformity of direction of grain, density, and other physical characteristics might be obtained; and (*c*) a greater variety of material would thus be made available for study.

It was decided, therefore, to modify the hot plate to accommodate test specimens which were 5 in. square. This was accomplished by constructing a second heating plate which was similar to the first except that the isolated central portion of each copper face was a 4 in. square. The winding of the main heater and auxiliary heater was identical to that used in the first tests. Most of the tests were run with this modified heating plate. Each specimen was surrounded during the progress of a test by a 12 in. square shell of oak lumber with a central opening 5 in. square into which the test specimen was inserted. The thickness of the shell, 1 in., fixed the thickness of all specimens.

The entire plate assembly was supported in a frame of wooden construction, as indicated in Figs. 1 and 2, which was designed to permit a constant pressure of 120 lb upon the specimens in all tests.

Power input to the main heater was measured with a watt meter. A recording potentiometer connected to copper-constantan thermocouples was used to obtain the temperatures of the surfaces of the hot and cold plates.

Test Materials

Test specimens were prepared from the wood of 40 tree-species most of which are of commercial importance in the United States. The lumber from which most of these test specimens were cut was supplied from the wood collections of the Department of Wood Technology, New York State College of Forestry.

All boards from which test specimens were to be cut were carefully machine-planed to a thickness of 1 in. to afford close surface contact with the plates. The two specimens required for each test were cut from successive portions of the same board in order that they would, insofar as possible, present identical and uniform characteristics. All specimens were sawed closely to the size of 5 in. square for a good fit with the surrounding guard-ring of wood.

Data were desired from as many species as possible for a range of moisture contents below the point of fiber saturation. Although the most satisfactory method would have been to test the same pair of specimens under several conditions of moisture equilibrium, the time factor involved in such treatment made this procedure impractical.

Several pairs of specimens were usually prepared from the same board and subjected to different moisture conditioning treatments. At least one pair of specimens, usually more, was tested at the moisture content prevail-

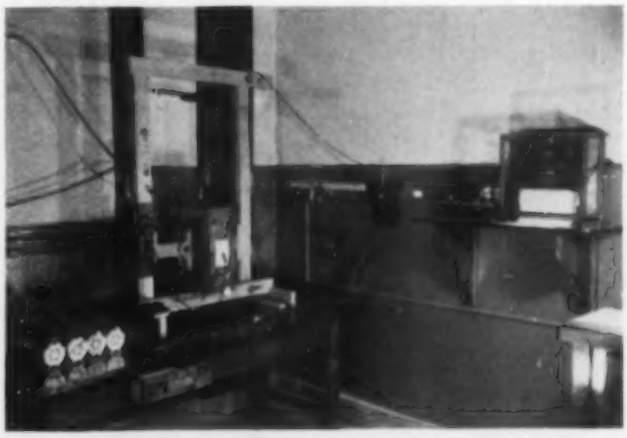


Fig. 1—General view of plate assembly and measuring equipment

*Assistant Professor of Forestry, University of Washington.

[1]The Measurement of Thermal Conductivity, by Ezer Griffiths and G. W. C. Kaye. (*Proceedings*, Royal Society of London, (A) 104: 71-98, 1923).

[2]Über die Wärmetechnischen Eigenschaften der Hölzer, by Franz Kollmann. (*Gesundheits Ing.* 57: 224-27, 1934.)

[3]The Heat Conductivity of Wood at Climatic Temperature Differences, by F. B. Rowley. (ASHVE TRANSACTIONS, Vol. 39, 1933, p. 329.)

[4]The Thermal Conductivity of Heat Insulators, by M. S. Van Dusen. (ASHVE TRANSACTIONS, Vol. 26, 1920, p. 385).

ing at the time of selection. Samples were selected from each board for the determination of moisture gradients. In no test was the inequality of moisture distribution unsatisfactory from the standpoint of heat conductivity determinations, although differences between core and shell were commonly one to two per cent.

Different specimens from the same board were moisture conditioned in a humidity chamber maintained with a constant relative humidity of 43 per cent, for which the equilibrium moisture content of wood is approximately 8 per cent, and in a constant humidity room maintained at 70 per cent relative humidity. Under the latter condition wood will gradually approach a constant weight, and when at an equilibrium with the atmosphere at room temperature it will contain nearly 14 per cent of moisture. To hasten this slow process of absorption, these specimens were steamed, care being taken to prevent condensed vapor from dripping upon them, until their moisture content was slightly higher than 14 per cent and then were placed in the constant humidity room to permit diffusion of moisture throughout the wood. In either chamber or room the specimens were conditioned for a period of four to six weeks, afer which moisture gradients were determined from sample specimens with results similar to those previously described.

Testing Procedure

The specimens were weighed before and after each test, but because many observations showed that the loss in weight was insignificant at the moisture contents tested, the second weighing was eventually discontinued. From 2 to 7 hours were required to bring the temperatures of the two faces of each specimen to equilibrium with approximately 45 F difference in temperature between the two faces. Upon the attainment of the steady state, temperature readings were taken, power input was determined, and thickness of the test pieces was measured, providing the necessary data for calculation of conductivity.

The volume of each specimen at the time of test was computed from a measurement of its dimensions. Upon

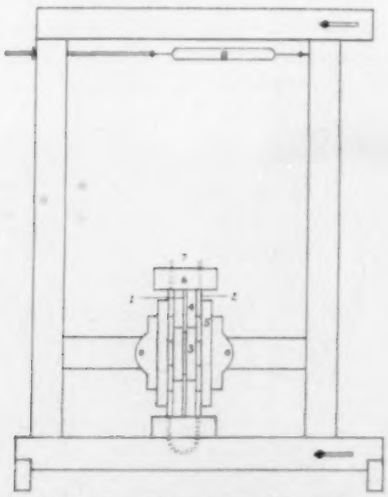


Fig. 3 — Plate assembly and frame

1. hot plate
2. cold plate
3. test specimen
4. wooden guard ring
5. cold plate support
6. corkboard insulation
7. water inlet and outlet
8. spring balance

Table 1—Test Data from Heat Conductivity Determinations

Species	Direction of Grain[a]	Density Lb Per Cu Ft	Moisture Content Per Cent	Conductivity k
Red oak	R & O	37.4	10.2	1.14
	R & O	37.4	14.8	1.14
	R & O	38.1	8.8	1.17
	R	38.1	14.5	1.20
	R & O	38.7	8.5	1.05
	R & O	38.7	8.3	1.14
	R	39.3	8.4	1.13
Southern red oak	O	38.7	11.7	1.02
	O	39.3	8.1	0.940
	R & O	42.4	13.7	1.27
	O	43.1	6.2	1.09
	O	43.1	5.9	1.15
	R & O	43.7	11.2	1.21
	R & O	45.0	7.6	1.14
	R & O	41.8	10.8	1.11
	R & O	42.4	10.3	1.05
	O	42.4	10.1	1.00
	O	42.4	11.0	1.05
	O	42.4	10.3	1.05
	O	43.1	10.1	1.05
	R	38.7	13.4	1.06
	R	39.9	8.4	1.12
	R	39.9	9.7	1.18
	R	39.9	9.1	1.17
	R & O	40.6	8.1	1.10
White oak	O	36.2	15.0	1.12
	O	37.4	9.3	1.00
	O	38.1	8.9	1.04
	R	40.0	15.0	1.26
	R & O	41.8	7.1	1.19
	R	42.4	9.2	1.10
	R	42.4	10.8	1.14
	R	42.4	8.9	1.17
Chestnut	R & O	29.4	12.1	0.890
	R & O	29.4	12.3	0.849
	R & O	29.4	13.7	0.840
	T & O	29.4	12.4	0.820
	T & O	30.0	12.2	0.808
	R & O	30.0	12.9	0.852
	R & O	30.0	12.3	0.921
Paper birch	R & O	33.7	14.6	0.959
	R & O	35.0	9.0	0.913
	R & O	35.0	9.4	0.935
	R & O	35.0	8.5	0.868
	R & O	35.0	8.7	0.946
Yellow birch	R & O	36.2	14.7	1.01
	R & O	36.8	9.6	0.906
	R & O	36.8	7.1	0.946
	R & O	36.8	7.0	0.985
	R & O	36.8	7.0	0.976
	R & O	36.8	6.9	0.966
	O	37.5	8.8	0.905
	O	37.5	10.5	0.905
American elm	R & O	36.2	9.3	0.985
Hackberry	R	36.2	9.5	1.01
	R	36.8	8.5	1.01
	R	36.8	8.4	1.01
Bitternut hickory	R & O	46.8	9.8	1.27
Butternut	R	24.4	9.0	0.709
	T	27.5	8.4	0.688
Cucumber magnolia	R & O	26.8	12.1	0.825
	R & O	26.8	12.2	0.848
Tulip poplar	R & O	30.0	14.7	0.840
	R & O	30.6	7.1	0.786
	R & O	30.6	7.8	0.799
	R & O	30.6	9.1	0.834
	R & O	30.6	7.5	0.784
	R & O	31.2	7.0	0.784
	R & O	33.7	6.7	0.848
	R & O	33.7	7.7	0.950
Hop hornbeam	R	44.9	10.4	1.04
Blue beech	R & O	39.9	10.8	1.22
	R & O	39.9	11.6	1.22
	O	40.6	11.5	1.16
Basswood	R	22.3	8.5	0.714
	R	22.5	7.8	0.729
	R	22.5	8.9	0.720
Black willow	R & O	25.0	10.4	0.775
Sassafras	R & O	28.1	10.1	0.944
Oregon myrtle	R & O	31.8	11.1	0.990
Silver maple	O	34.4	10.2	0.950
	R	35.0	10.6	1.10
Striped maple	T	30.6	11.1	0.863
	T	30.6	11.1	0.885
	T	31.8	11.4	0.926
Bigleaf maple	R	35.6	8.5	1.07
	R	36.2	9.7	1.15
	R	36.2	14.0	1.18
	R	36.8	8.0	1.09
	R	36.8	7.9	1.10
Black gum	R	36.8	9.3	1.09
	R	38.7	9.6	1.15
	R & O	39.9	9.2	1.16
Red ash	R & O	31.2	9.7	0.874
	R & O	31.8	9.8	0.912
	R & O	31.8	8.3	0.862
	R & O	32.5	8.9	0.885

Table 1—Test Data from Heat Conductivity Determinations—(Continued)

Species	Direction of Grain[a]	Density Lb Per Cu Ft	Moisture Content Per Cent	Conductivity k
White ash	T	39.9	9.4	1.10
	T	39.9	8.8	1.06
Balsa	O	6.86	9.0	0.383
	O	6.86	8.6	0.380
	O	6.86	13.3	0.415
	O	6.86	8.7	0.369
	O	6.86	8.6	0.380
	O	7.50	9.3	0.389
Western white pine	O	23.1	14.7	0.720
	O	23.7	7.7	0.610
	R	24.4	13.5	0.8[illegible]
	R	25.0	7.0	0.[illegible]55
Loblolly pine	T & O	32.5	16.2	1.08
	O	33.7	11.9	1.09
	T & O	34.3	11.6	1.04
	R & O	34.3	17.7	1.03
	T & O	35.0	21.0	1.22
	T & O	35.6	15.7	1.13
	T & O	36.2	12.3	1.02
Shortleaf pine	T & O	33.1	13.1	1.02
	T & O	33.1	16.0	1.03
	O	33.7	11.3	0.965
	T & O	35.0	13.2	1.08
	R & O	39.3	10.9	1.04
	R & O	40.6	12.9	1.23
	R & O	30.6	14.4	1.00
	R & O	31.2	8.9	0.892
	R	32.4	9.0	0.904
Longleaf pine	O	38.1	17.2	1.18
	O	38.7	14.6	1.16
	T & O	38.7	17.1	1.24
	O	39.3	13.3	1.14
	O	39.3	13.0	1.10
	O	39.9	12.2	1.14
	T & O	39.9	16.6	1.21
	T & O	40.6	14.4	1.28
	O	41.2	12.2	1.14
Northern white pine	R & O	22.5	7.6	0.691
	R & O	23.1	7.8	0.662
	R	25.0	14.0	0.801
	R	25.6	7.6	0.778
	R	25.6	8.9	0.717
	R	25.6	6.3	0.711
	R	25.6	7.4	0.749
	R	25.6	6.7	0.705
	T & O	26.2	13.6	0.749
	T & O	26.9	8.1	0.696
	T & O	26.9	8.0	0.688
	R	26.9	6.7	0.696
	R	26.9	9.0	0.755
	R	26.9	6.8	0.714
	R	26.9	8.9	0.729
	R	26.9	14.3	0.813
	R	27.4	5.5	0.726
	R	27.4	7.7	0.795
Norway pine	R	25.6	14.9	0.845
	R	25.6	14.5	0.828
	R	26.2	8.2	0.765
	R	26.2	8.1	0.810
	R	26.8	7.6	0.753
	R	26.8	7.0	0.779
	R	26.8	7.2	0.784
Lodgepole pine	R	28.7	11.0	0.808
	R	30.0	14.8	0.910
	R	30.6	9.1	0.892
	R	30.6	9.7	0.875
	R	30.6	9.2	0.840
Ponderosa pine	R & O	26.8	18.1	0.886
	R & O	28.1	10.6	0.814
	R & O	28.1	10.2	0.802
	R & O	29.3	9.8	0.837
	R & O	29.3	7.2	0.802
	R	29.9	9.1	0.849
	R	29.9	8.4	0.840
	R	29.9	8.5	0.862
Limber pine	R	23.7	9.1	0.709
	R	23.7	11.1	0.712
	R	23.7	10.1	0.706
	R	23.7	16.2	0.753
	R	24.3	10.5	0.717
owland white fir	O	27.5	8.6	0.758
	O	27.5	8.5	0.760
	O	28.1	5.0	0.685
	O	28.1	5.0	0.735
	O	28.1	5.0	0.773
	O	28.1	5.4	0.738
	O	28.1	14.4	0.779
	O	28.7	8.6	0.764
	O	29.3	11.6	0.845
	R & O	29.9	11.5	0.805
	R	31.2	13.8	0.810
	R	32.5	8.3	0.765
	R	32.5	8.3	0.765
Engelmann spruce	R & O	26.2	9.2	0.651
	R & O	26.2	9.7	0.676
	R	26.8	8.7	0.630
Douglas fir	R	29.9	9.6	0.799
	R	30.6	7.4	0.796
	R	30.6	10.0	0.825
	R	30.6	14.0	0.909
	R	31.2	7.7	0.793
	R	31.8	7.3	0.795

Table 1—Test Data from Heat Conductivity Determinations—(Continued)

Species	Direction of Grain[a]	Density Lb Per Cu Ft	Moisture Content Per Cent	Conductivity k
Southern cypress	R	25.6	14.4	0.779
	R & O	25.6	14.4	0.735
	R & O	25.6	8.9	0.732
	R & O	25.6	8.5	0.726
	R & O	26.2	7.4	0.703
	R & O	26.2	6.3	0.755
	R & O	26.2	6.5	0.767
	R & O	26.2	6.7	0.773
	R & O	26.2	5.8	0.642
	R & O	26.2	5.9	0.755
	R & O	26.2	5.6	0.732
	O	26.2	9.2	0.781
	R & O	26.9	9.6	0.746
	R & O	26.9	10.4	0.735
	R & O	26.9	8.0	0.729
	R	26.9	9.6	0.712
	R	26.9	7.8	0.643
	R	26.9	8.6	0.706
	O	19.4	15.3	0.865
	O	19.4	15.9	0.868
	O	19.4	14.6	0.813
	O	20.0	13.5	0.860
	T	20.6	16.6	0.779
	T	21.2	16.5	0.723
	T	21.2	14.2	0.823
	T	21.9	11.8	0.724
	T	21.9	11.2	0.685
	T	22.5	11.0	0.674
Western red cedar	R & O	18.1	9.4	0.578
	R & O	18.1	15.1	0.625
	R & O	18.1	13.3	0.634
	R	17.5	8.9	0.590
	R	17.5	9.3	0.572
	R	18.1	8.9	0.581
	R	18.1	9.2	0.564
	R & O	18.7	7.5	0.581
Southern white cedar	R	18.1	13.8	0.645

[a]R—radial, T—tangential, O—oblique (intermediate between radial and tangential).

the conclusion of the entire series of tests, each specimen was dried to constant weight at 221 F in order to obtain a direct measurement of its moisture content at the time of test as well as to permit a direct calculation of its specific gravity on the basis of oven-dry weight and volume at the time the conductivity determination was made.

Experimental Results

The data from a total of 236 heat conductivity determinations which were made at a mean temperature of 82 F are shown in Table 1, which presents the conductivities of individual test specimens together with the information necessary for their interpretation.

In his study of the heat conductivity of a considerable number of American woods, Professor Rowley[5] presented data from a large number of individual determinations. The incorporation of these values with those presented in Table 1 offered three advantages: (*a*) an extension of the range of moisture content in the determination of its effect upon conductivity; (*b*) a larger sampling of the materials studied which permitted the drawing of more accurate generalizations as to the effect upon conductivity of the several factors involved; and (*c*) a statistical comparison of the test data with those obtained by Professor Rowley as a check upon their reliability.

Accordingly the data from 313 individual tests upon wood at moisture contents below the fiber-saturation point were obtained from the published results[6] which are the result of research sponsored by the ASHVE in cooperation with the *National Lumber Manufacturers Association*, conducted at the University of Minnesota.

[5]Loc. Cit. Note 3.
[6]Loc. Cit. Note 3.

Conductivity as Related to Density and Moisture Content

A correlation of heat conductivity with density and moisture content as independent variables was the first step in an analysis of the raw data compiled from the two sources previously mentioned. The previous work[7] had already indicated that differences between species are not so great as to preclude treatment of the problem with complete disregard for such factors as are involved in different species and different directions of transverse heat flow.

Of the several methods which are adaptable to the study of a relationship involving three variables, that is, density, moisture content, and heat conductivity, an alinement chart appeared to be most suitable. A chart consisting of two straight axes, parallel to each other, and an intermediate curved axis was found to answer the requirements of the problem.

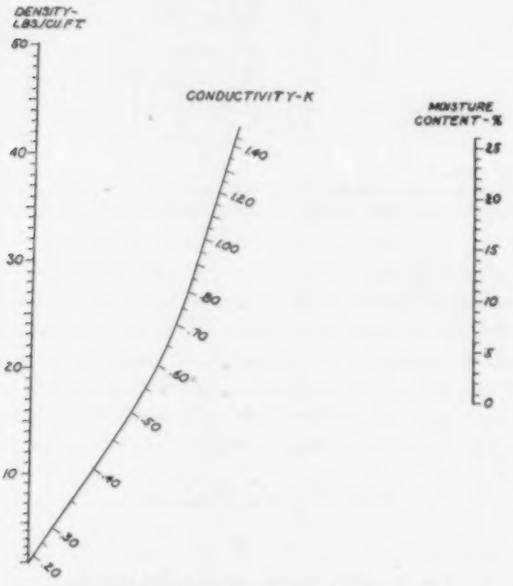


Fig. 3—Alinement chart representation of relationship between transverse heat conductivity, density, and moisture content

k = Btu per square foot per degree Fahrenheit per inch per hour
Density = pounds of dry wood per cubic foot at time of test
Moisture Content = per cent based upon weight of water and oven-dry weight of wood

The relationship which exists between the transverse heat conductivity of wood and the two independent variables, density and moisture content, is shown in the resultant chart, Fig. 3. In this chart, conductivity k is expressed in Btu per square foot per degree Fahrenheit, per inch, per hour; density, in pounds of dry wood per cubic foot at the time of test; and moisture content, in per cent based on the weight of water and the oven-dry weight of the wood. The value for the conductivity of a specimen of wood at any definite density and moisture content can be read from the intermediate axis by placing a straight edge across the chart connecting the values of the two independent variables. For greater convenience in visualizing the variation in conductivity

[7]Loc. Cit. Note 3.

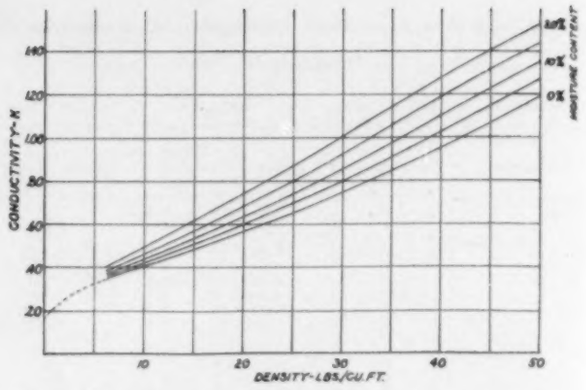


Fig. 4—Relationship between transverse heat conductivity of wood, density, and moisture content (plotted from values of Fig. 3)

with density and moisture content changes, the curves shown in Fig. 4 were prepared from the alinement chart values.

At any fixed moisture content below the fiber-saturation point, conductivity increases with increasing density at a slightly accelerated rate for the higher densities within the range of the experiment, although at the higher moisture contents (15-20 per cent) the increase follows more nearly a straight-line relationship. Since the conductivity of wood represents the resultant conductivity of the wood substance present as well as that of the included air and moisture, the extension of the zero per cent moisture curve to zero density was made on the basis of a fixed point (0.168) for the conductivity of air when convection and radiation effects have been removed. The same reasoning was followed in fixing the position of the lower extreme of the conductivity axis in the alinement chart.

The fact that a mere extrapolation of the line representing zero per cent moisture content would lie considerably above the broken line curve, Fig. 4, might be taken as evidence that radiation or convection, or both, play some part in the transfer of heat in wood, at least insofar as the lighter woods which were examined are concerned. For if these phenomena were completely ineffective, the extrapolated curve would be expected to intersect the indicated value of the conductivity of air.

An increased moisture content is shown to raise the heat conductivity of wood at any fixed density (a condition not realized in any one specimen since the density varies in accordance with the degree of swelling) about 1.2 per cent (0.7-1.8 per cent) for each per cent increase in moisture content.

Statistical treatment of the data revealed a fairly high degree of correlation between conductivity and the two independent variables. The correlation index was found to be 0.932 which may be interpreted to mean that 86.8 per cent of the total variance in conductivity exhibited by the data is associated with density and moisture content.

Comparison of Data

It will be recalled that the data upon which the alinement chart is based were obtained in part from the researches of Professor Rowley and the remainder from the results of the present investigation. An opportunity

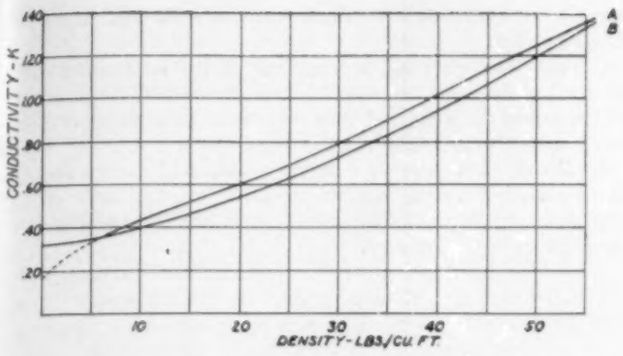


Fig. 5—Transverse heat conductivity of wood at 10 per cent moisture content (*A* = Values from alinement chart; *B* = Values from Kollmann's empirical equation)

was thus afforded for a comparison of these data. The results of the two experiments show an average difference of 0.861 per cent. This slight difference cannot be considered significant but may be attributed to an accident of sampling due to the dispersion of the data about the plotted curves.

In passing, it is of interest to compare the plotted alinement chart values for the heat conductivity of wood at 10 per cent moisture content with those due to the empirical equation which was proffered by Kollmann[8]. These are shown in Fig. 5. Attention is called to the fact that in this graph density was calculated on the basis of the total weight of wood and moisture at 10 per cent moisture content. Over the greater portion of the range of density considered here, the rate of increase in conductivity is comparable to that stated by Kollmann, but the values due to his equation are approximately 10 per cent lower than those presented in this paper. Kollmann[9] republished this equation together with the results of additional individual determinations about two years after its original presentation. On the basis of Kollmann's augmented data the plotted values obtained from the equation obviously require some upward adjustment, and the results of the present study as shown in Fig. 5, curve *A*, confirm the advisability of a revised equation.

Evaluation of Other Factors

In order to determine whether differences in the structure of wood, such as those which contrast the hardwoods and softwoods, might affect conductivity, a procedure identical in principle to that used in comparing the experimental data from two sources was followed. These differences were found to exercise an inappreciable influence upon the transverse conductivity of heat.

The same statistical procedure lends itself to an evaluation of the influence upon transverse heat conductivity exerted by direction of grain (whether radial or tangential with respect to the annual rings). Previous investigators[10] have stated that conductivity is slightly greater in the radial direction of the wood than it is in the tangential direction. Professor Rowley[11] tentatively concluded that in species with strongly marked spring- and summer-wood tangential conductivity is somewhat greater than radial conductivity, but that no appreciable difference exists between conductivities in these two directions in woods which possess uniformity of structure throughout the annual ring.

The results as obtained from hardwoods and softwoods were analyzed separately. The values which resulted from the calculation serve only to indicate that radial conductivity is significantly greater than that in the tangential direction in the hardwoods generally, whereas in the softwoods no superiority in the radial direction was detectable. These results, insofar as the hardwoods are concerned, are in agreement with those of Griffiths and Kaye,[12] and it appears probable that their approximation of a conductivity 5 to 10 per cent greater in the radial direction than in the tangential direction is reasonably correct.

All previous investigations on the heat conductivity of wood have listed the constant for each kind of wood. The density-conductivity relationships shown by Rowley and Kollmann together with the high correlation index of the alinement chart arising from the present work have shown that the influence of factors peculiar to any one species is relatively slight.

Table 2 shows the average percentage deviation in the conductivity of each species from that estimated by means of the alinement chart. The results of the present experiment are shown in column 1. So that the listing may be as complete as possible, Professor Rowley's data have been included in the same column in the case of species which were not examined by the author. When

Table 2—Variation Between Species in the Conductivity of Heat

Species	Average Percentage Deviation from Alinement Chart Values			
	(1) Independent Experimental Results	Number of Tests	(2) Combined Experimental Results	Number of Tests
Red oak	6.4	7	5.2	27
Southern red oak	— 0.9	12		
White oak	0.6	8	3.2	22
Chestnut	— 3.2	7		
Paper birch	— 5.2	5		
Yellow birch	— 6.4	8	— 6.5	36
American elm	— 2.3	1	5.5	7
Hackberry	0.5	3		
Bitternut hickory	— 0.2	1		
Butternut	— 6.4	2		
Cucumber magnolia	2.9	2		
Tulip poplar	— 4.8	8		
Hop hornbeam	—16.0	1		
Blue beech	5.5	3		
Basswood	7.2	3		
Black willow	3.9	1		
Sassafras	16.1	1		
Oregon myrtle	7.6	1		
Silver maple	4.4	2		
Striped maple	— 0.8	3		
Bigleaf maple	10.8	5		
Hard maple[a]	2.7	8		
Soft maple[a]	— 1.8	6		
Black gum	6.5	3		
Red ash	— 0.6	4		
White ash	— 1.5	2	0.7	9
Balsa	0.9	6		
Western white pine	— 0.6	4		
Loblolly pine	3.2	7		
Shortleaf pine	2.2	9	6.2	43
Longleaf pine	0.5	9	— 0.4	17
Northern white pine	— 1.9	18	1.2	27
Norway pine	3.4	7	2.7	16
Lodgepole pine	— 0.7	5		
Ponderosa pine	— 0.2	8	4.0	41
Limber pine	— 1.4	5		
Sugar pine[a]	— 4.3	6		
Western larch[a]	— 2.0	7		
Lowland white fir	— 6.7	13		
White fir[a]	— 8.0	9		
Engelmann spruce	—14.4	3		
Sitka spruce[a]	— 8.1	8		
Western hemlock[a]	— 9.0	28		
Eastern hemlock[a]	3.0	8		
Douglas fir	— 5.6	6	— 9.3	19
Southern cypress	0.7	24	1.4	57
Redwood[a]	6.4	9		
Western red cedar	— 2.3	8	— 1.8	18
Southern white cedar	1.8	1		

[a]Data from Rowley's investigations. Loc. Cit. Note 3.

[8]Loc. Cit. Note 2.
[9]Technologie des Hölzes, by Franz Kollmann. (*Berlin: Springer*, 1936, p. 111.)
[10]Loc. Cit. Note 1.
[11]Loc. Cit. Note 3.
[12]Loc. Cit. Note 1.

a species was studied in both investigations, the results are combined (column 2), in order to obtain a broader base for the estimation of differences between species in heat conduction after adjustment for those variations due to density and moisture content has been made.

Individual species with few exceptions are shown to vary in conductivity within comparatively narrow limits about the estimated values from the alinement chart. The greatest average deviations are based upon a very small number of observations and require additional study for their verification. A comparison of the values of this investigation, with those obtained through the incorporation of Professor Rowley's results, indicates that average variations in conductivity within a few per cent, which are based upon a comparatively small number of observations, cannot be considered to arise from characteristics inherent within a species. Variations of this order of magnitude within the wood of a single species are apparently dependent upon the source of the material.

Many of the average deviations from the alinement chart values for those species which have been tested seem to be quite closely related to the sub-microscopic structure of the cell walls. In general, coniferous wood of moderate growth from such species as Engelmann spruce, Sitka spruce, western hemlock, lowland white fir, white fir, and Douglas fir averages from 5 to 15 per cent lower in transverse conductivity of heat than would be anticipated from a consideration of density and moisture content alone. Among the hardwoods the birches appear to be distinguished by a transverse conductivity somewhat lower than normal, while bigleaf maple and basswood are likely to exceed the alinement chart values for conductivity across the grain by 5 to 10 per cent.

No evidence of variation in heat conductivity, because of chemical composition of wood, was detected although the species which were examined showed considerable diversity in composition. The enhanced density of extremely resinous specimens of the southern pines, for example, appears to counteract the additional conducting ability of the resin itself.

Summary

1. A hot-plate method has been used for the determination of transverse heat conductivity in a large number of different woods. The apparatus was designed to test reasonably small wood samples and permits the selection of specimens for uniformity of structure, density, and moisture content.

2. The results of the study have been combined with the data from an independent source in order to provide a broad basis for an evaluation of the several factors which influence the conductivity of wood.

3. A rather high correlation was found to exist between heat conductivity and density and moisture content in wood below the fiber-saturation point, which allows the use of an alinement chart designed to show the inter-relationship between heat conductivity and these two variables. The alinement chart also made possible a direct comparison of the test data of this study and those determined by Professor Rowley. An average difference of less than 1 per cent was found between the two sets of data. This amount is not significant statistically.

4. Radial conductivity was found to exceed tangential conductivity in the hardwoods by a comparatively small but significant amount. This difference may reasonably be attributed to the influence of the radially oriented wood rays. The ray volume in the softwoods is so small that this differential influence is insignificant.

5. The type, size, and arrangement of the longitudinal cells in wood, at least insofar as they are contrasted in the structure of hardwoods as compared with softwoods, have no appreciable effect upon the transverse conductivity of heat.

6. Peculiarities in gross structure or chemical composition of the wood of individual species appear to exercise little or no influence upon thermal conductivity, other than that due to the resultant change in density.

7. Within the wood of any one species the relationship between conductivity and density may deviate considerably from that determined from a study of a large number of specimens from different species. This departure results presumably from the occurrence of a type of wood which is abnormal with respect to the sub-microscopic structure of the cell wall.

Acknowledgment

The experimental work from which this paper has been prepared was conducted in 1935-36 in partial fulfillment of the requirements for the Ph.D. degree, New York State College of Forestry, Syracuse. The author wishes to express his appreciation to all who assisted in the completion of this project, particularly to Prof. H. P. Brown and Prof. C. C. Forsaith, New York State College of Forestry, Prof. Walter H. Meyer and Prof. B. L. Grondal, University of Washington, and to Prof. F. B. Rowley, director, Engineering Experiment Station, University of Minnesota, for his valuable data included with those of the present study.

Western Michigan Elects Officers at Annual Meeting

May 20, 1940. The annual meeting of the Western Michigan Chapter was held at the Walnut Hills Country Club, East Lansing. The afternoon was spent at games, such as barnyard golf, golf, etc., with prizes being awarded.

Dinner was served to 71 members and guests, followed by the appointment of tellers to count the ballots, which resulted in the following officers elected to serve for the 1940-41 season:

President—T. D. Stafford
Vice-President—W. G. Schlichting
Secretary—F. C. Warren
Treasurer—H. J. Metzger
Board of Governors—B. F. McLouth, H. J. Young and C. H. Pesterfield.

The evening program was provided by Prof. Brick Burhans, Michigan State College, and a group of boys who gave a very interesting exhibit of boxing, wrestling and fencing.

The chapter voted its disapproval to the proposed method of selecting the Nominating Committee and instructed its representative to make sure he is present to express the chapter's views accordingly.

The meeting was adjourned at 10:30 p.m.

Golden Gate Chapter Holds Annual Meeting

May 7, 1940. At the annual meeting of the Golden Gate Chapter the following officers were elected to serve for the ensuing year:

President—N. H. Peterson
Vice-President—C. E. Bentley
Secretary—J. A. Hill
Treasurer—J. F. Kooistra
Board of Governors—R. A. Folsom, E. W. Simons and C. L. Peterson.

The following committees were appointed by the president to serve for the coming year:

Program—C. E. Bentley, chairman; R. B. Holland, R. A. Parker, T. J. White and F. W. Kolb.

Membership and Attendance—G. M. Simonson, general chairman. *Membership*—C. D. Williams, chairman; Mason Emanuels

and G. G. Harrison. *Attendance*—E. J. Rosen, chairman; E. J. Ploskey, Edward Hill, Jr. and G. G. Harrison.

Technical—R. A. Folsom, general chairman. *Weather Data*—J. A. Hill, chairman; O. W. Johnson and James Gayner. *Cooling Tower*—E. W. Simons, chairman; W. W. Cockins and T. J. White.

Minnesota Members Elect Officers

May 13, 1940. The May meeting of the Minnesota Chapter was held at the Golden Valley Golf Club, with 35 members and guests attending. Due to rather inclement weather only 14 members played golf in the afternoon, with a good attendance on hand for the 19th hole at 6:00 p.m., and dinner in the main dining room at 7:00 p.m.

Pres. F. C. Winterer called the meeting to order at 8:15 with the report of the nominating committee, and Neil Adams moved that the report be accepted and that the secretary be instructed to cast a unanimous ballot for all nominees. The motion was seconded by Prof. F. B. Rowley and after put to a vote was passed. The following are the officers elected to serve for the coming year:

President—M. H. Bjerken
Vice-President—H. M. Betts
Secretary-Treasurer—D. B. Anderson
Board of Governors—F. C. Winterer and William McNamara.

President-Elect Bjerken then made a few remarks on plans for the coming year and Neil Adams spoke briefly on the importance of obtaining new members.

Michigan Holds Joint Meeting with *ASME* and *NWAHACA*

April 20, 1940. The chapter held its 7th annual dinner-dance at Dearborn Inn, with 103 present, including members, guests and friends.

A social hour with organ music in the lobby was held from 6:30 to 7:30, and dinner was served at 8:00 p.m. in the main ballroom, with dancing to the music of Dave Diamond and his orchestra. The party ended at 1:00 a.m., with everyone reporting a delightful evening.

March, 5, 1940. The regular March meeting of the Michigan Chapter was held at Huyler's in the Fisher Building, and was sponsored jointly by the *American Society of Mechanical Engineers* and the *National Warm Air Heating and Air Conditioning Association.* There were approximately 135 members of the affiliated Societies and guests present. Immediately following dinner the meeting was called to order by B. W. Beyer, chairman of the *ASME.* F. R. Bishop introduced Prof. S. Konzo, special research professor, University of Illinois, who spoke on the domestic power plant.

President Randall introduced J. R. Scott, manager of the Winter Air Conditioning Department, Surface Combustion Corp., who spoke on gas as a fuel.

C. R. Miller, consulting engineer, Socony-Vacuum Oil Co., was then introduced by President Randall, and gave an interesting talk on oil as a fuel.

L. J. Whitlock, Jr., district manager, Coal Bureau of the Norfolk and Western Railroad Co., was the next speaker, and he discussed coal as a fuel.

Professor Konzo then commented upon the remarks of Messrs. Scott, Miller and Whitlock and showed his colored film displaying stoker combustion.

This was followed by a general discussion and the meeting was adjourned at 10:45 p.m.

John Meyers Dies of Heart Attack

John Meyers, a specialist in the field of automatic temperature, humidity and instrument controls, died suddenly from a heart attack at his home on Sunday, June 9, at the age of 39.

Mr. Meyers was graduated from the University of Pennsylvania with a B.S. degree in mechanical engineering with the class of 1923. He immediately entered the employ of the Johnson Service Co. at their Philadelphia office as a salesman. His rise to responsibility was rapid and in 1926 he was appointed manager of the Baltimore office and later he assumed the management of the Washington office, which position he held until his death.

His continuous services in the Baltimore-Washington area placed him in contact with most of the important heating, ventilating and air conditioning installations made during the last 15 years. He joined the Society in 1937 and took an active interest in its activities. He will be greatly missed by his many friends and associates in the Washington, D. C., Chapter.

John Meyers was married to Helen Thorburn Sommerville of Staunton, Va., March 17, 1937. Besides his widow he is survived by his father, George J. Meyers and a brother, George J. Meyers, Jr., of Philadelphia, Pa., to whom the Officers and Council extend their sincere sympathy.

Interment was in the cemetery adjacent to the Presbyterian Church, Mitchells, Va., Wednesday, June 12.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 17 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by July 15, 1940, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
AY, EDWARD L., Asst. Engr., Library of Congress, Washington, D. C.	G. D. Fife John Meyers	F. M. McEntee M. F. Hoppe

CANDIDATES

BAILEY, JAMES L., Asst. Chief Engr., Parks-Cramer Co., Charlotte, N. C. (*Reinstatement*)

BECKWITH, F. J., Htg. Engr., Crane Co., Jacksonville, Fla.

BROWN, HARPER JUNIUS, Engr., Meadville, Pa.

FARRINGTON, S. EDWARD, Engr., Moody & Hutchison, Philadelphia, Pa.

GOODMAN, C. E., Mgr., Trane Co. of Canada, Ltd., Halifax, N. S.

HANNIGAN, WILLIAM, Bldg. Supt., Acacia Mutual Life Ins. Co., Washington, D. C.

HYDE, L. L., Gen. Mgr., Gruden Co., St. Paul, Minn.

LAWRENCE, C. T., Br. Mgr., U. S. Radiator Corp., Minneapolis, Minn.

LUNN, ROBERT J., Student, University of Minnesota, Minneapolis, Minn.

MCCREA, LESTER W., Mfrs. Repr., Baltimore, Md. (*Reinstatement*)

MERGARDT, ALBERT P., Pres. and Mgr., American Htg. Engrg. Co., Inc., Washington, D. C.

METZGER, ALBERT FRANK, Supervisor of Steam Utilization, Allegheny Co. Steam. Htg. Co., Pittsburgh, Pa.

ROGERS, CHARLES S., Htg. Engr., L. P. Steuart & Bro., Inc., Washington, D. C.

SATTERLEE, HARRY A., Partner, The Schulte Plbg. & Htg. Co., Joplin, Mo.

SCHLICK, P. F., Br. Mgr., Grinnell Co., Inc., St. Paul, Minn.

WEBBER, CHARLES H., Sales Engr., Pacific Scientific Co., Los Angeles, Calif.

REFERENCES

Proposers	*Seconders*
W. B. Hodge	T. C. Cooke
W. M. Wallace, II	C. E. Petty
J. C. Pastor	F. H. Gaylord
M. C. Gillett	C. J. Stermer
A. N. Volkhardt	C. W. Capes (*Non-Member*)
H. R. Wemple, Jr. (*AIEE*)	I. G. Jalonack
J. E. Hutchison	S. E. Plewes
L. E. Moody	K. F. K. Rugart
J. W. O'Neill	J. P. Fitzsimons
S. A. Jennings	G. E. Cole
F. E. Spurney	I. M. Day
W. E. Heibel	F. A. Leser
A. W. Schultz	F. C. Winterer
F. H. Schernbeck	William McNamara
F. H. Schernbeck	F. C. Winterer
William McNamara	C. E. Gausman
F. B. Rowley	A. B. Algren
R. C. Jordan	C. E. Lund
M. F. Blankin	H. H. Erickson
M. C. Gillett	C. F. Dietz
R. H. Feltwell	F. A. Leser
W. E. Kingswell	T. H. Urdahl
J. F. Collins, Jr.	D. W. Loucks
F. B. Mahon	W. W. Stevenson
R. H. Feltwell	F. A. Leser
W. E. Kingswell	I. M. Day
Sidney Pines	Ernest Webb
Benjamin Cook	Maurice Peiser
D. M. Forfar	C. E. Gausman
F. C. Winterer	William McNamara
J. B. Griffith	E. H. Kendall
J. F. Park	A. J. Hess

CANDIDATES ELECTED

In the past issues of the JOURNAL of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Committee on Admission and Advancement and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. B-III, Sec. 8, of the By-Laws, the following list of candidates elected:

MEMBERS

BUCK, DAVID T., Pres., Buck Engrg. Co., Freehold, N. J. (*Advancement*)

DRAIN, HARRY E., Dist. Repr., Warren Webster & Co., Des Moines, Ia.

GRIFFIN, CHARLES J., Engr.-Custodian, Board of Education, Chicago, Ill.

JANOS, WILLIAM A., Mech. Engr., Western Electric Co., New York, N. Y.

JENKINS, SYDNEY D., Mgr. Htg. Dept., Bell & Morris, Calgary, Alta., Can.

LEWIS, H. FREDERICK, Vice-Pres., Harvey A. Dwight Oil Heat & Supply Co., Inc., Albany, N. Y. (*Advancement*)

MATZEN, HARRY B., Cons. Mech. Engr., New York, N. Y. (*Reinstatement*)

NUTTING, ARTHUR, Chief Engr., American Air Filter Co., Louisville, Ky. (*Reinstatement*)

PEACOCK, HERBERT, Dist. Mgr., Carrier Corp., Washington, D. C. (*Reinstatement*)

QUACKENBUSH, SEELYE M., Owner, Quackenbush Co., Buffalo, N. Y.

TODD, MERYL L., Mech. Engr., Waterloo, Iowa. (*Advancement*)

ASSOCIATES

BAYLES, ROBERT W., Mgr., Htg. Div., James Morrison Brass Mfg. Co., Ltd., Toronto, Ont.

BISPALA, JOHN T., Htg. Engr., Bispala Bros., Hibbing, Minn.

BLAZER, BENJAMIN V., Owner, M. Blazer & Son, Passaic, N. J.

DAHLGREN, GUSTAVE E., Insulation Mgr., Thorkelsson Ltd., Winnipeg., Man.

GORGEN, ROY E., Owner, Roy E. Gorgen Co., St. Paul, Minn.

GRANDIA, WILLEM M., In charge Air Cond. & Refrig. Div., Pacific Commercial Co., Manila, P. I.

HEPBURN, EWEN M., Br. Mgr., Empire Brass Mfg. Co., Ltd., Winnipeg, Man.

LEIBY, ROBERT S., Contractor, Columbus, Ohio

MINER, H. HARVEY, Partner, Miner Supply Co., Red Bank, N. J.

MOORE, MACDONELL, Pres. & Gen. Mgr., The Moore Fuel Corp., Danbury, Conn.

THOMPSON, CHARLES, Sales & Design, Builders Wholesale Supply Corp., Reno, Nev. (*Reinstatement*)

JUNIORS

DEEVES, EDWARD W., Partner, Fred Deeves & Sons, Calgary, Alta.

FOGG, JOSEPH H., Sales Engr., B. F. Sturtevant Co., Alexandria, Va.

GRAY, HAMILTON E., Partner, Gray Engrg. Co., High Point, N. C.

HILL, WALTER W., Engr., United Clay Products Co., Washington, D. C.

LEVITT, LEROY L., Air Cond. Engr., Calvert Distilling Co., Relay, Md.

PAINE, H. ALLAN, Mech. Engr., Toltz, King & Day, Inc., St. Paul, Minn.

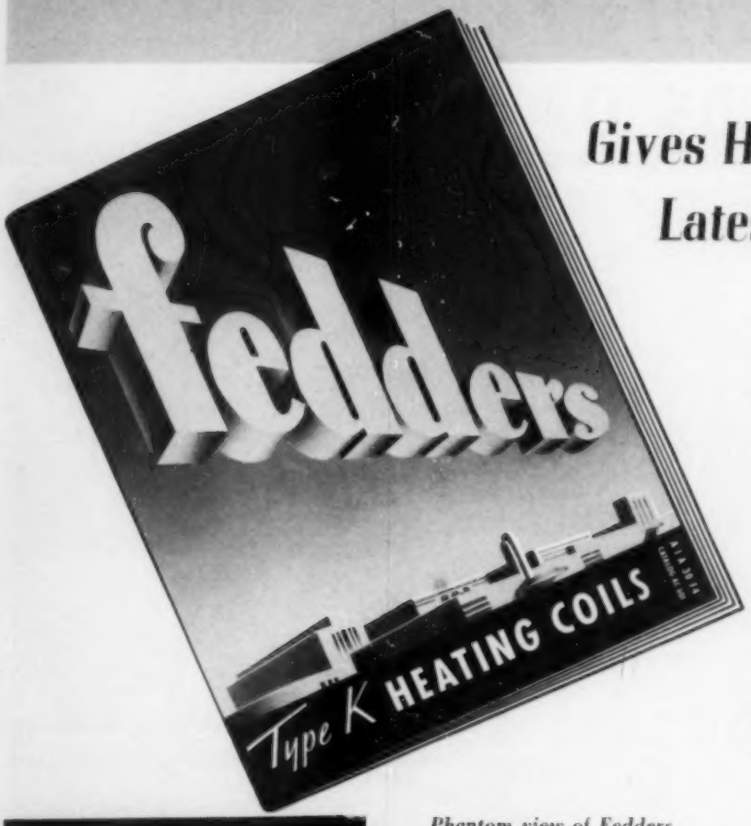
PETERSON, J. RAYMOND, Draftsman, Gausman & Moore, St. Paul, Minn.

PROSSER, ROBERT G., Sales Engr., The Trane Co., Minneapolis, Minn.

STUDENT

ZAKI, HUSSEIN M., Student, Purdue University, West Lafayette, Ind.

Every Man Responsible for Designing Heating Systems is INVITED TO SEND FOR THIS NEW BOOK



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Seven Base Models from 1½ to 25 Tons Capacity.

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MANUFACTURING CO., INC.
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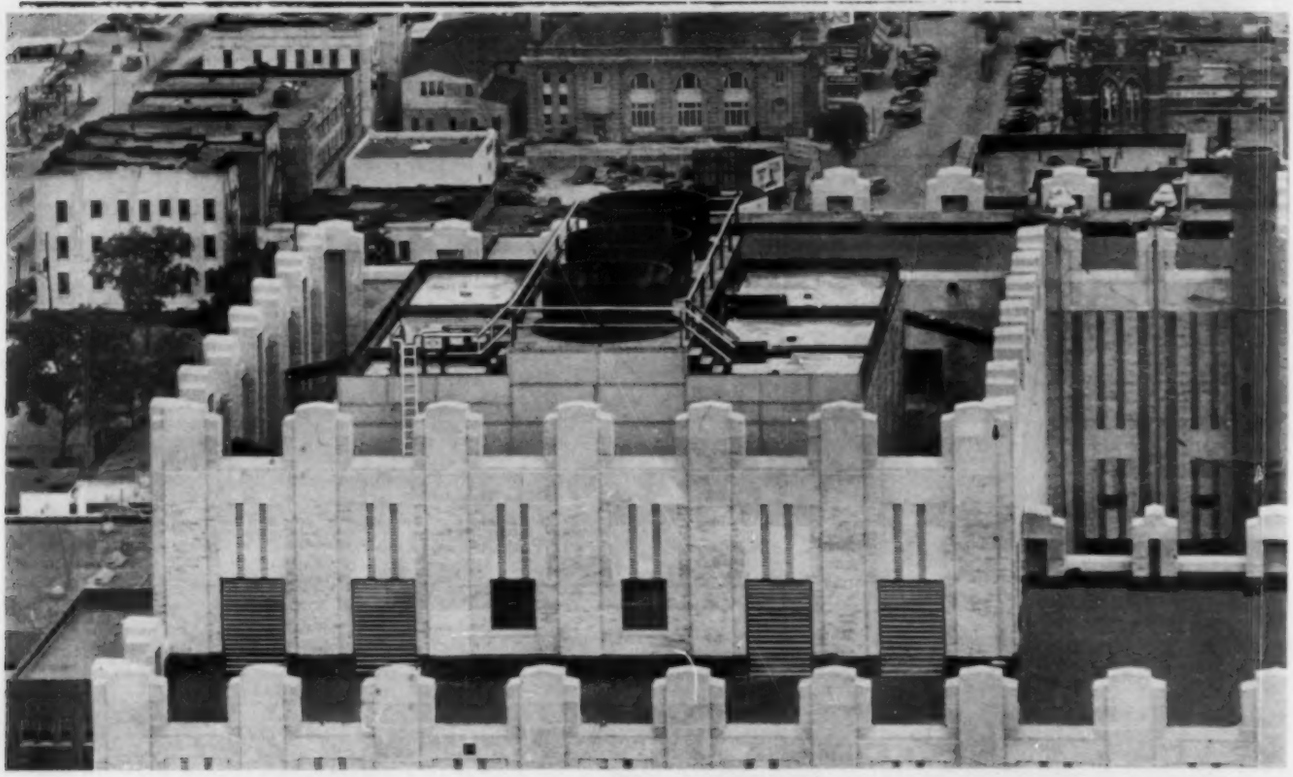
SAVE on WATER COOLING COSTS

for Any Air Conditioning or Refrigeration System

from a TWO TON capacity to MANY HUNDREDS OF TONS



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Each Engineered to the Individual Service!

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ALL Types of COOLING TOWERS

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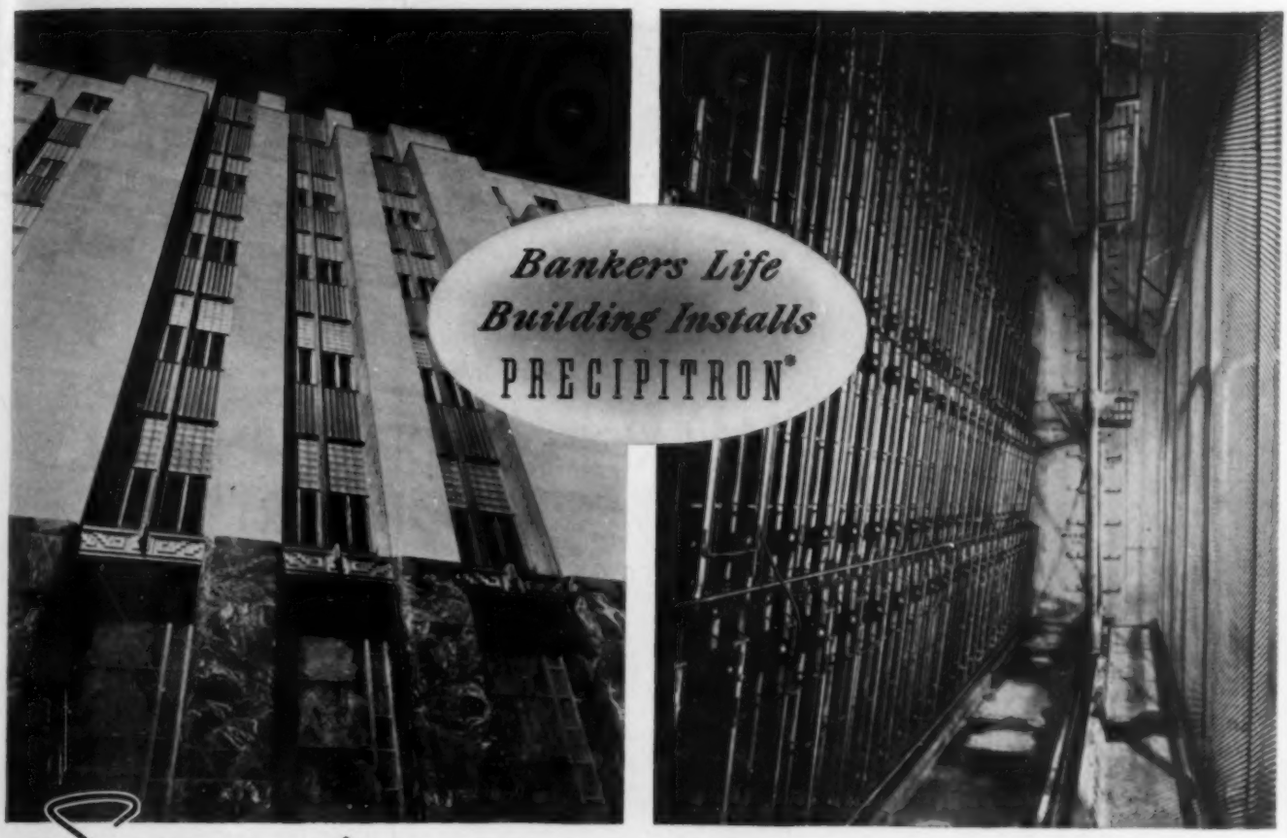
with Patented Side-Injection

ALL TYPES for Air Washers, Brine Spraying, Atmospheric Condensers, Cooling Towers, Humidifying, Ice-Melting, etc. Many sound reasons why they lead in sales and installed capacity

The upper illustration shows a Marley "Small Series" unit for indoor service with systems of 2 to 20 tons. Below is a Marley "Double-Flow" Induced Draft tower of 4,000 G.P.M. Marley also supplies Standard Induced Draft, Forced Draft and Atmospheric Towers, individually engineered to requirements.



Safeguards INTERIOR WITH ELECTROSTATIC AIR CLEANING

Acclaimed by architects, engineers and contractors alike as the most modern building of its kind, the new Bankers Life Building in Des Moines, Ia., has installed complete PRECIPITRON equipment to protect the building interior from the ravages of dust, dirt and grime. 182 Precipitron cells are used to clean the air electrostatically for all seven floors. Their capacity is 124,000 cubic feet of air per minute.

Innovations in heating, air conditioning and air cleaning for this most modern structure, the design of which is primarily functional and which incorporates many construction innovations, were worked out by Charles S. Leopold, well-known Philadelphia consulting engineer, with installations by the Pennsylvania Engineering Corporation of Philadelphia.

The Precipitron was specified by the consulting engineer to provide the greatest possible protection for the building interior and its valuable documents and records. So efficient is the Precipitron that it removes air-borne matter as small as 1/250,000 inch in diameter, including tobacco smoke. This efficiency was considered of great importance because of the necessity of removing minute particles which cause untold damage to interiors, furnishings, decorations, documents and delicate operating machinery. It is also important in reducing cleaning, decorating and maintenance costs.

The Precipitron is being used to clean the air and protect interiors, equipment and delicate operating mechanism in Office Buildings, Hospitals, Stores and Shops, Textile Mills, Steel Mills, Telephone Exchanges, and many other applications where dust and dirt are a costly hazard.

If you have a dust and dirt problem, the nearest Westinghouse Sales Office will provide complete details on the Precipitron. Or write Westinghouse Electric & Manufacturing Company, Precipitron Department, Edgewater Park, Cleveland, Ohio.

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IMPROVE YOUR KNOWLEDGE OF AIR CONDITIONING

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Here is a book that presents—in simple, readily understandable form—every kind of information necessary for an accurate and thorough knowledge of air conditioning principles, equipment, and practices. Written by S. R. Lewis, a widely-known consulting engineer who has been active in air conditioning work for more than thirty years, it deals with all angles of the air conditioning subject from the practicing engineer's viewpoint. The designing procedures explained in the book are, for example, in every detail the same procedures employed today by the author's own organization.

Featuring this third edition are several entirely new chapters on phases of the subject not previously treated, including noise control, air conditioning measurements, air conditioning standards, fire protection codes and operating suggestions. Brand new designing examples are also used, together with new forms for recording the design data, the proper filling-in of which is explained step-by-step.

The chapter devoted to Psychrometry presents nineteen different formulas for psychrometric calculations. In illustrating the correct use of these formulas, Mr. Lewis applies both the psychrometric tables and chart in order to render both devices thoroughly understandable. The chart used in this edition is less complex than the one used in his previous book.

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Engineers in air conditioning will find the new "Air Conditioning for Comfort" invaluable as a reference book, while salesmen, students, and others may rely on it to give them a clear knowledge of fundamentals, and of the latest air conditioning methods and equipment.

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CHAP. 5—The Psychrometric Table and Chart
CHAP. 6—Humidity Controllers and Control
CHAP. 7—Heat Transmission Through Barriers
CHAP. 8—Ventilation, Solar and Appliance Heat
CHAP. 9—Heating Systems
CHAP. 10—Air Conditioning Systems
CHAP. 11—Air Conditioning Apparatus
CHAP. 12—Refrigeration and Refrigerants
CHAP. 13—Refrigeration Compressors and Condensers
CHAP. 14—Refrigeration Evaporators and Auxiliaries
CHAP. 15—Record Forms for Heating and Cooling
CHAP. 16—Air Distribution
CHAP. 17—Water in Air Conditioning
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Heat Exchange Surface

Cleanable Tube Unit with Removable Header

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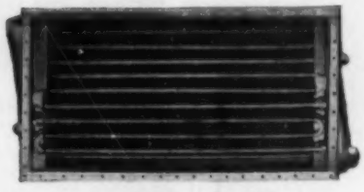
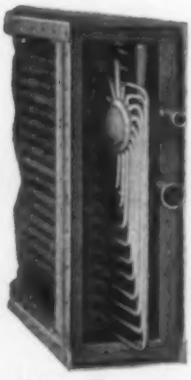
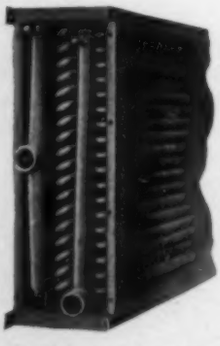


Universal Aerofin



Direct Expansion Unit with Centrifugal Header

PROVEN PERFORMANCE



Aerofin Continuous Tube Water Coil

- **Aerofin Fan System Heat-Exchange Surface is adaptable to meet all practical requirements of refrigeration.**
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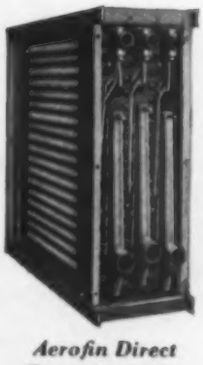

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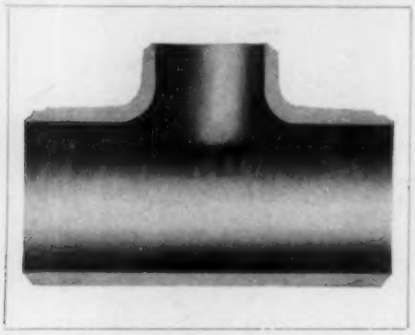
Equipment DEVELOPMENTS

For your convenience in obtaining more information about any of this equipment, see coupon on page 126. Add the new products and companies listed here to your Directory Section which you received in your January, 1940, HEATING, PIPING AND AIR CONDITIONING and thus keep your records of sources of supply up to date throughout the year . . . Single asterisk (*) indicates equipment not listed in Directory Section; double asterisk (**) equipment and manufacturer not listed

Seamless Steel Welding Tees

No. 1893—The principal feature of a new line of seamless steel welding tees is that full pipe strength is attained through the proper placing of metal at points of higher stress, according to the manufacturer. The design provides substantially more metal thickness at the crotch. The thickness from this point (that is, along the top center line of the run of the tee) is gradually reduced to nominal at the bottom of the tee where stresses, when reinforcement at more highly stressed points is ample, again reach normal.



Another feature is that longer outlets are provided for ease in lining up and welding. The tees are accurately machined, scale free and stress relieved.—Tube-Turns, Inc., 238 East Broadway, Louisville, Ky.

Small Size Steam Traps

No. 1894—Two new steam traps, designated as Nos. 800 and 801, supersede the small "200 series" traps formerly produced by the manufacturer. Features of the traps include rugged construction, with more metal added at connecting points and around water passages, free flow of water due to redesigned cross-section of water passages, one piece stainless steel buckets, and single casting size for both ½ and ¾ in. pipe connections.

CURTIS Packaged Air Conditioners Offer Your Customers EFFECTIVE, EFFICIENT, LOW-COST COOLING

CURTIS REFRIGERATION AIR CONDITIONING AND COMMERCIAL

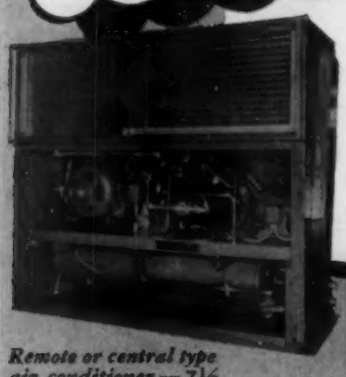
It's easy—and profitable—to meet the fast growing public demand for comfort cooling with the complete line of Curtis Packaged Air Conditioners. Five models, 3, 5, 7½, 10 and 15 ton capacity.

Curtis units have the advantage of complete factory design and assembly and are precision engineered throughout, made of the highest quality materials.

When you sell the Curtis line you can meet the requirements of all classes of retail establishments, offices and residences and at the same time offer the following advantages at surprisingly low cost.

- Units are self-contained, semi-portable, easily moved
- Can be installed in one day without disturbing fixtures
- Air is cooled, dehumidified, circulated and filtered
- Low first cost—readily financed
- Maximum efficiency—quiet, economical operation
- Attractive external appearance
- Adaptable for heating if desired

Get your share of the growing sales and profits in the packaged air conditioning field. For full information write to Curtis today.



Remote or central type air conditioner—7½, 10 and 15 ton sizes

Packaged type store cooler —3 and 5 ton sizes

CURTIS REFRIGERATING MACHINE CO.

Division of Curtis Manufacturing Co.

1950 Kienlen Avenue St. Louis, Missouri

Established 1854

The No. 800 is for use on straight through pipe connections, and the 801 for standard angle connections. Either may be equipped for "blast" trap service by using buckets which have an auxiliary thermic air vent. Both traps have the inverted bucket operating principle, free floating valve mechanisms, self-scrubbing action, heat treated chrome steel valve seats, and stainless steel valve levers.—Armstrong Machine Works, 874 Maple St., Three Rivers, Mich.

Largest Centrifugal Machine

No. 1895*—A contract for "the largest centrifugal refrigerating machine in the United States" has been awarded by the Industrial Rayon Corp. The machine—a 1,000 ton turbo-compressor—in combination with a brine cooling system is also "the world's largest single unit refrigerating system using the refrigerant Freon-11 (trichloromonofluoromethane)."

This system will be used for industrial process air conditioning in an addition to the present $11,500,000 Industrial Rayon plant at Painesville, Ohio.

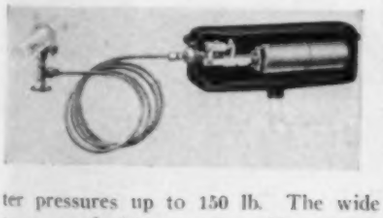
A unique feature of this refrigeration unit is its steam turbine drive, which will be completely automatic in operation. Exhaust steam from the generating turbines will be used as a source of power—thus allowing the generated electric power to be used elsewhere in the plant and reducing operating expense. This type of equipment was selected because of its reduced space requirements and efficient operation.

Four thousand gallons per minute of Lake Erie water will be used in condensing the refrigerant gases of the cooling system. This system will cool 2600 gpm of brine to 40 F.

Air conditioning is indispensable in maintaining proper temperatures and humidities in the various stages of rayon manufacture, and is especially important at this Industrial Rayon plant, in which every department is air conditioned. There, instead of being wound on a bobbin after the chemical spinning process and handled repeatedly, the yarn is bleached, treated, dried and twisted before it is ever wound into a package. As a single thread it moves continuously forward—through processing liquids, cleaning baths and over drying reels—at all times protected by proper temperature and moisture content in the surrounding air. A product highly uniform in qualities and physical characteristics is the result—York Ice Machinery Corp., Roosevelt Ave., York, Pa.

Humidifier Water Control

No. 1896—A new snap action valve for humidifier and water control has been designed to eliminate the possibility of sticking or clogging under lime and scale conditions. A cam and roller action causes it to snap from tight closure to wide open whenever the water level drops ¼ in., according to the manufacturer. When the water level rises to the proper height the valve snaps to the closed position, seating tight against water pressures up to 150 lb. The wide opening feature is said to assure flushing out the orifice and cleaning the seat each time the valve operates.



This control is made in three different styles for installation in any type of existing plant. One style consists of the valve and float only, 10 7/16 in. in length. Another includes the valve and float in a covered float chamber, size 11 in. long x 3 in. wide x 4 7/8 in. deep. The third adds copper tubing and a simple means of tapping into the city water supply line.—McDonnell & Miller, 400 N. Michigan Ave., Chicago, Ill.

Warm Water Heating System

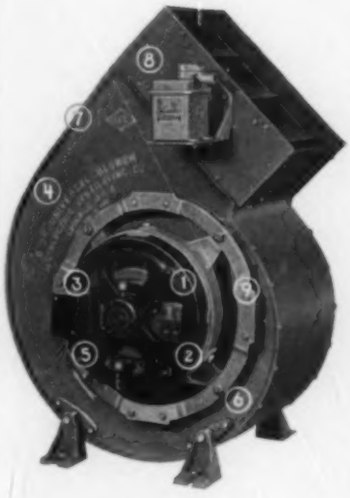
No. 1897—A newly announced one pipe warm water heating system—offered by the maker as a "contribution to the low cost housing field"—includes the circulator (illustrated), the flow

PIONEERING ILG LEADERSHIP

"Firsts"

NUMBER 2 OF A SERIES

Friction-Free
DIRECT-CONNECTED
UNIVERSAL BLOWERS



① ILG MOTORS built solely and specifically for Ilg Blowers in conformance with A. I. E. E. Standards.

② DIRECT CONNECTION of motor and wheel—popularized by ILG—patented 1910 . . . no money-wasting friction from belts, gears or sheaves.

③ SPACE-SAVING—Mounting of direct-connected motor in the side of the blower requires little more floor space than housing alone.

④ RUGGED CAST IRON SIDES—Rigid, extra quiet.

⑤ PERMANENT ALIGNMENT of motor and wheel—"factory-set"—minimizes wear and vibration.

⑥ ONE-NAME-PLATE GUARANTEE—All parts, including motor, designed and built under one roof—undivided responsibility!

⑦ UNIVERSAL DISCHARGE—64 standard arrangements for vertical, horizontal and angle discharges, right or left motor mountings, etc.

⑧ VARIABLE AIR CONTROLLER—Patented 1926. Manually or electrically (A. C.) operated. No power waste from variable motor speed. No belts or costly slip ring motors. Extra equipment.

⑨ "FLOATED DRIVE" BRACKETS—Patented 1932. Motor mounting rides on rubber cushions, totally eliminating noise and vibration of metal to metal contact. Extra equipment.

⑩ FULL LINE of forward curved and backward curved non-overloading type blowers; also small volume blowers.

⑪ TYPE B-C BLOWER has an aluminum backward curved wheel for lightness with strength.

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★ Placed direct-connected propeller fans on production basis—1906
★ Self-cooled miracle motor that "breathes"—patented—1906
★ Type C (condensor-type) Motors—1925
★ Penthouses or power roof ventilators—1915
★ Automatic shutter—1907
★ Motor operated shutter—1918
★ Solenoid operated shutter—1907
★ Propeller fan steam unit heater—1916
★ Self-contained electric unit heater—1917
★ ILGATTIC system of summer cooling—1918
★ PORTABLE type kitchen ventilating fans—1918
★ Built-in type kitchen ventilating fans—1925
★ Transom type kitchen ventilating fans—1925

BEFORE YOU SPECIFY
WRITE ILG "FIRST"

★ Eight different models—sizes range from 9" to 60"

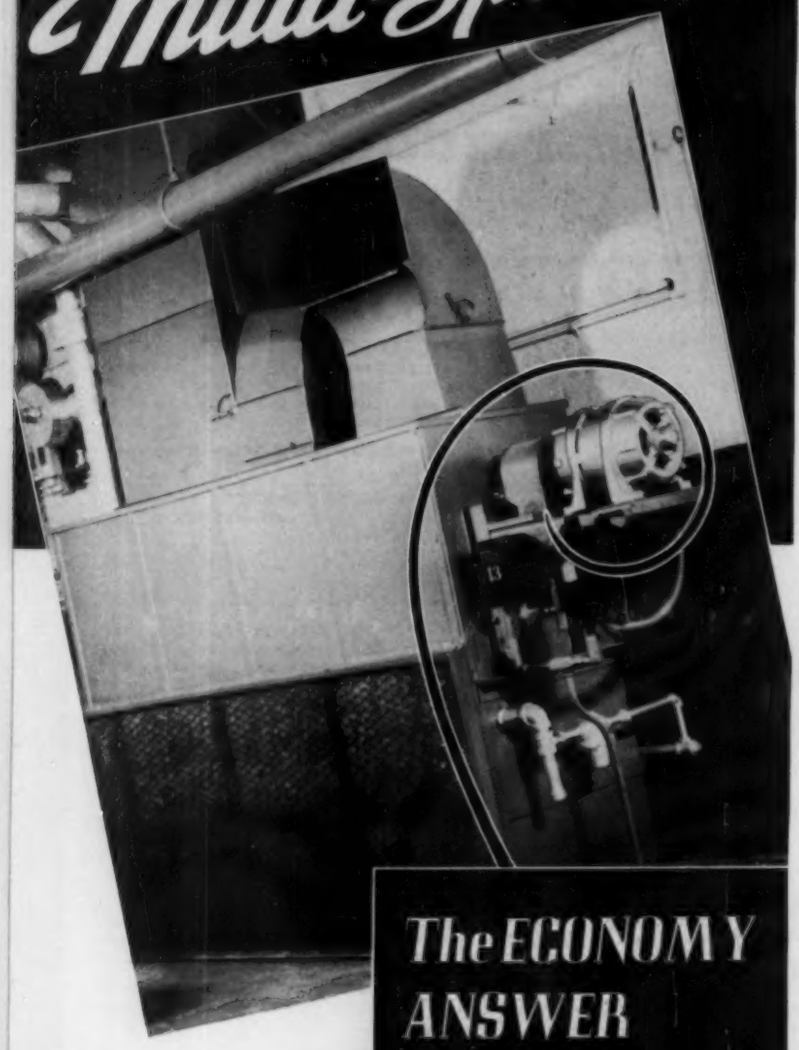
★ Easy to install—shipped from factory completely assembled, ready to bolt down four legs.

★ Complete catalog No. EB-381 is yours for the asking—write or phone our nearest office today.

ILG ELECTRIC VENTILATING CO.
2841 N. CRAWFORD AVENUE, CHICAGO, ILL.
Offices in 41 Principal Cities

ILG
Vitalized* VENTILATION
AND AIR CONDITIONING
*AIR CHANGE . . . NOT JUST AIR MOVEMENT!

HOWELL Multi-Speeds



HOWELL Two-Speed, Variable Torque Multi-Speed Motor driving unit heater. Low speed is used in mild weather; high speed used on severely cold days to step up heating capacity.

The ECONOMY ANSWER to MOST Multiple Speed Drives . . .

A PIONEER in multi-speed motor development, HOWELL has a wealth of experience from which you can profit. Whenever more than one operating speed is necessary, it will pay you to consult with us because: ***HOWELL Multi-Speed Motors are of far more simple construction, as compared to slip-ring motors—THUS LOWER FIRST COST—and, of course, lower maintenance!***

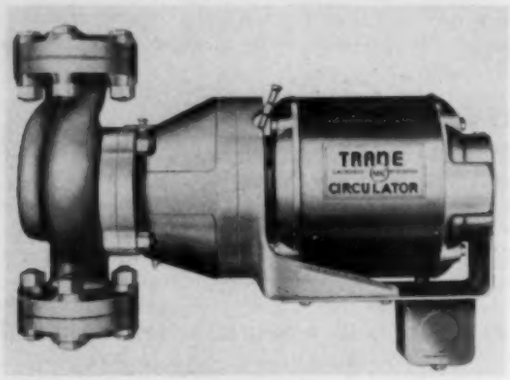
These HOWELL Multi-Speeds are obtainable as 2, 3 or 4-speed motors in sizes ½ to 150 HP — ideal for driving fans, blowers, unit heaters, unit coolers, compressors, centrifugal pumps, etc. And like all other HOWELL Motors, they are ***precision built, precision tested.*** Write us, outlining your problem!

1915 · 1940 HOWELL MOTORS 25th Anniversary Year

HOWELL ELECTRIC MOTORS COMPANY
HOWELL, MICHIGAN
Representatives in All Principal Cities

valve, the flow fitting, the automatic feed and relief valve and the convectors.

The flow valve permits circulation of hot water when heat is required and offers complete control of circulation. The fitting



is available for both iron and copper pipe, and is attached to the return from each convector. The purpose of the automatic feed and relief valve is to maintain the right amount of pressure for proper operation.

The convectors are available in a wide range of sizes and models to meet various individual requirements, including fully recessed, semi-recessed and free standing models.—Trane Co., La Crosse, Wis.

600 Lb Steel Valve

No. 1898—The main feature of a new 600 lb standard steel valve—called the "Duravalve Junior"—is the seat, which is stellite welded integral to the body. This construction eliminates any chance of leakage between seat and ring and body, the maker states. The valve disc is also heavily stellited to resist wire drawing and wear.

The body and bonnet are of carbon molybdenum steel, giving it a temperature rating of 950 F at 600 lb steam pressure. The valve is available in sizes ¼ to 1 in. inclusive, in the globe type, with either screwed or socket welding ends.—Hancock Valve Div., Manning, Maxwell & Moore, Inc., 11 Elias St., Bridgeport, Conn.

Thermostatic Trap Element

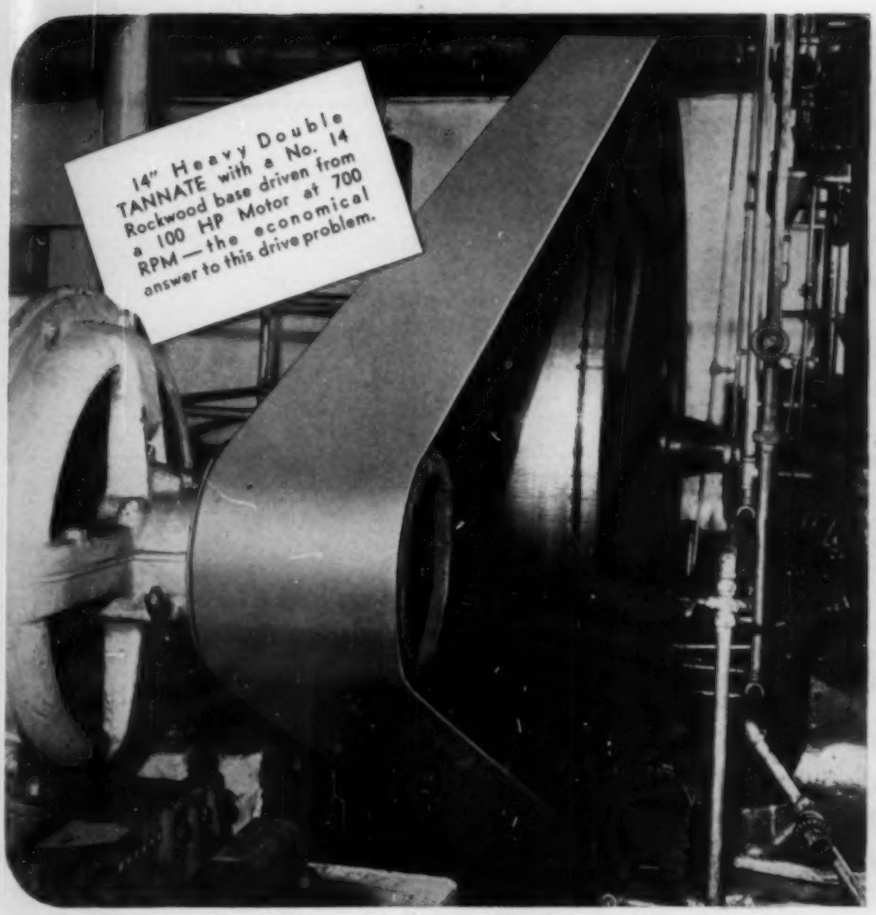
No. 1899—The addition of several new sizes of the "Cage Unit," a thermostatic operating unit for trap renewal, now makes it possible to repair practically every make of thermostatic trap without special tools or adjustments, according to the manufacturer.

The unit consists of a thermostatic element, stainless steel valve seat and plug, locked in correct adjustment for proper opening and closing temperatures. This feature eliminates the need for threading the element into the trap cover or making adjustments between the valve seat and valve piece, and thus simplifies the problem of trap repair, the maker states.

These replacement elements can be supplied in capacities ranging from 200 to 1200 EDR at 15 lb pressure, 130 to 800 lb per hr at 60 lb maximum pressure, and 275 to 1350 lb per hr at 125 lb maximum pressure.—Barnes & Jones, Inc., 128 Brookside Ave., Jamaica Plain, Boston, Mass.

Rotary Pump

No. 1900—A new compact herringbone gear rotary pump is built for small capacity and low pressure requirements. Applications include industrial fuel oil burners, lubrication systems, and many process piping services.


14" Heavy Double TANNATE with a No. 14 Rockwood base driven from a 100 HP Motor at 700 RPM — the economical answer to this drive problem.

On Refrigerating Compressor — — —

33% INCREASE IN EFFICIENCY using Tannate-Rockwood Drive!

The drive formerly used on this 50-ton refrigerating compressor showed slip at 15" to 18" vacuum pressure—operating on 17' centers with idler. Replaced by a Tannate-Rockwood drive, operating on 10' centers, nearly a 30" vacuum has been taken care of . . . one quarter less refrigeration has been required . . . efficiency has stepped up about 33% according to the engineer in charge!

Your drives can give performances equally fine. Let us show you how. No obligation; just write

J. E. RHOADS & SONS

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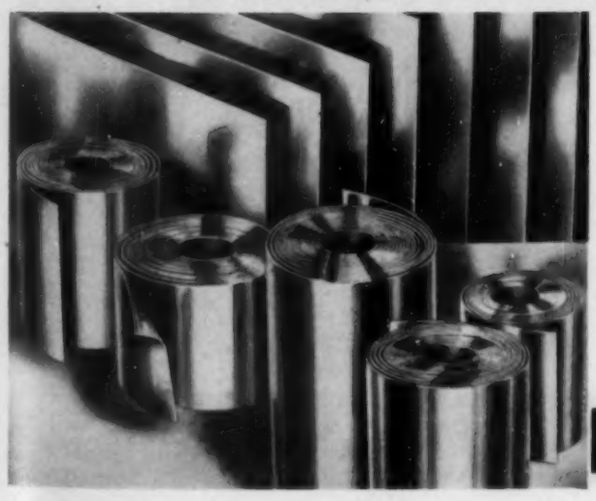
NEW YORK CHICAGO ATLANTA CLEVELAND

Factory & Tannery Wilmington Del.

Preferred FOR ALL AIR CONDITIONING JOBS

HUSSEY *Pure Lake* COPPER



Developed by nature in the crucible of Time, this premium grade copper is just naturally more enduring than ordinary copper, yet costs no more—a factor that makes Hussey the most widely preferred copper for all air conditioning jobs, large or small. You'll find Hussey Pure Lake copper easily available, too, through convenient warehouses everywhere. Check your nearest source of supply.

C. G. HUSSEY & COMPANY

(Division of Copper Range Co.)

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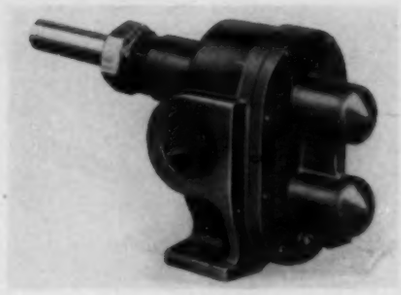
Copper HUSSEY *Brass*



The features are—according to the manufacturer — one stuffing box for minimum leakage, minimum floor space requirement, few parts, excellent suction lift qualities, four bearing construction for long life, force feed lubrication, high pump efficiency, and the use of efficient and quiet herringbone gears.

Smooth flow of liquid through these pumps maintains a steady discharge pressure. Standard motors of any make up to 1750 rpm can be used.—Worthington Pump & Machinery Corp., Harrison, N. J.

Snap Switch

No. 1901—The new "Con-Tac-Tor" snap switch incorporates a single pole, double throw switch with three built-in terminals. It is designed to break one set of contacts and then make the other set of contacts when actuated and there is no overlapping of break and make, according to the manufacturer. The following hook-ups are possible: (1) to make and break a two wire circuit, and (2) to break one circuit and make another when two circuits with a common wire are used. Direct or reverse action may be obtained by reversing the two outside terminals.

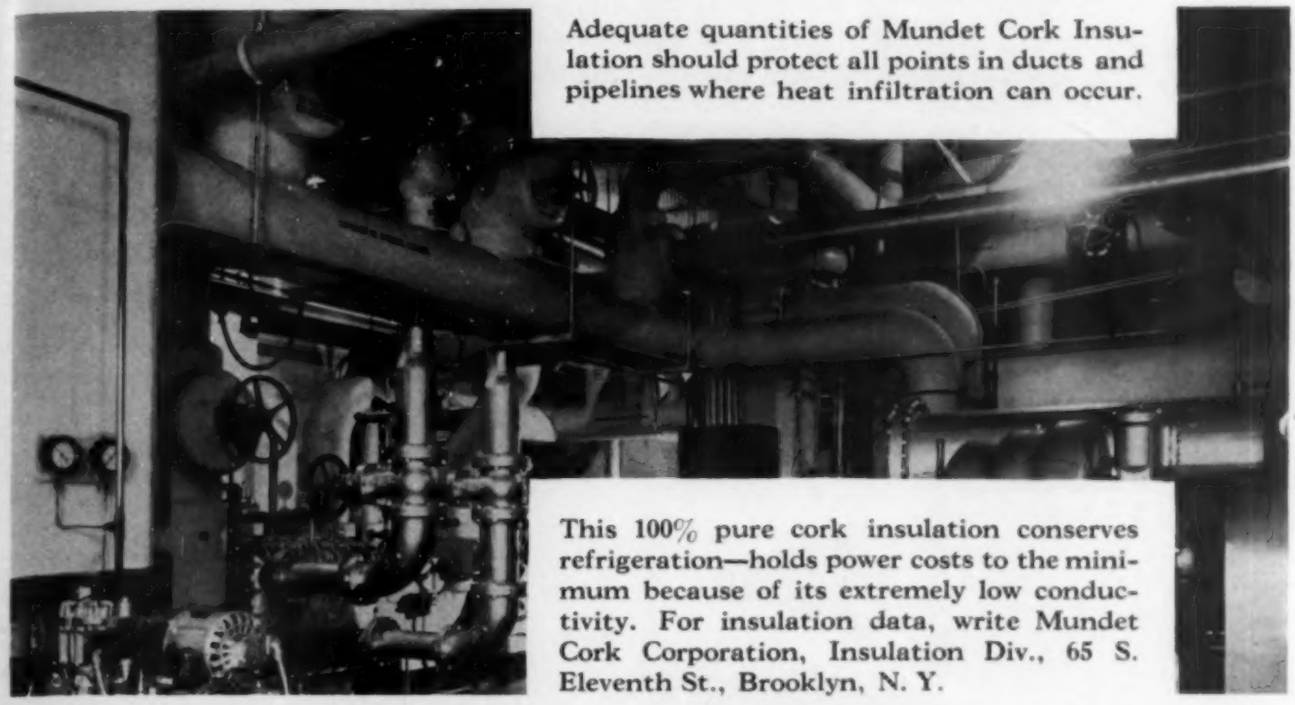
The switch is small in size (2 x 1 x ¾ in.), is entirely enclosed in a black bakelite case, and has an electrical rating of 1 hp, 110 volts a-c, and 1½ hp, 220 volts a-c. It may be installed in any position.—Minneapolis-Honeywell Regulator Co., 2701 Fourth Ave., S., Minneapolis, Minn.

Large Air Conditioners

No. 1902—New self-contained "Weathermaker" air conditioning units of large capacity—for use in stores, restaurants and other commercial establishments — feature a water cooled condensing unit and apparatus to cool, dehumidify, clean and circulate the air as standard equipment. With the provision for heating coil and humidifier, year 'round air conditioning is obtained.

These air conditioners are designed for location outside the space to be conditioned, the air distribution and return being handled by ducts with grilles. Four sizes are available, 5, 7½, 10 and 15 compressor motor horsepower.—Carrier Corp., 302 S. Geddes St., Syracuse, N. Y.

For Cost-Saving Efficiency in Air Conditioning



Adequate quantities of Mundet Cork Insulation should protect all points in ducts and pipelines where heat infiltration can occur.

This 100% pure cork insulation conserves refrigeration—holds power costs to the minimum because of its extremely low conductivity. For insulation data, write Mundet Cork Corporation, Insulation Div., 65 S. Eleventh St., Brooklyn, N. Y.

MUNDET Cork INSULATION

ONE BOILER for 23 FLOORS

The Philtower building, one of Oklahoma's finest office buildings, is heated by ONE firebox boiler.

The boiler as equipped with a Series F600W512 WECO-N. G. E. gas burner and a Series 14 Webster Combustion Controller will develop 36,500 sq. ft. of steam radiation. The heating plant contains one No. 5187 Kewanee Up-Draft Boiler, with a rated capacity of 24,290 sq. ft. of steam radiation. The NEW, Series 14 Webster Combustion Controller, combines the advantages of modulating and full-on and full-off control in a very flexible manner.

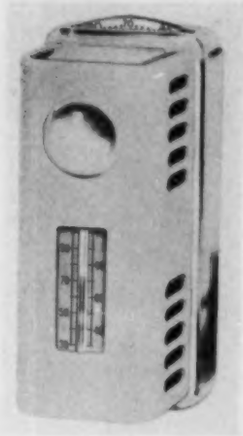
Write for bulletin describing this controller.

THE WEBSTER ENGINEERING CO., TULSA, OKLA.

Division of — SURFACE COMBUSTION CORP., TOLEDO, OHIO

Line Voltage Thermostat

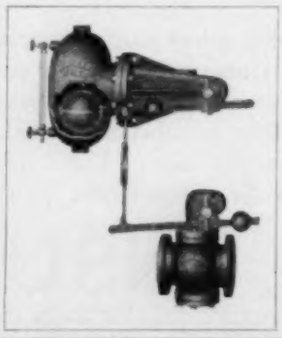
No. 1903—A new line voltage thermostat has been designed to fill two particular needs, according to the manufacturer. The first is for that of an instrument with an adjustable stop to limit the maximum temperature at which the control may be set. This is desirable, it is said, when the control of temperature setting is in the hands of someone other than the person paying for the heat.



The second requirement is that of a control with a setting for summer fan operation. The scale on the thermostat may be set up to "summer" without disturbing the winter temperature stop. The "S" on the dial projects through the side of the case and provides a reminder that the fan should be turned off at closing time. —White-Rodgers Electric Co., 1209 Cass Ave., St. Louis, Mo.

Liquid Level Controller

No. 1904—A new ball bearing liquid level controller is offered for smooth and accurate control of fluid levels in storage or process tanks, feedwater heaters, condensers and similar liquid containers. The assembly is also recommended by the maker as a continuous drainer to handle large volumes of condensate from vessels.



A mercury switch may be added when desired to ring an alarm bell or operate various colored lights. Controller and valve are made for a maximum working pressure of 600 lb at 750 F and the valves come in sizes up to 8 in.—McAlear Mfg. Co., 1901-1909 S. Western Ave., Chicago, Ill.

Hot Water Heating Fitting

No. 1905*—For providing adjustable water volume control for individual radiators on single pipe booster pump hot water heating jobs, a new "Positive Distributing" fitting has been developed. It consists of a brass casting in which a friction grip baffle plate is mounted. Adjustment is made by releasing a set screw and turning an adjusting cap which sets the baffle in any desired position.

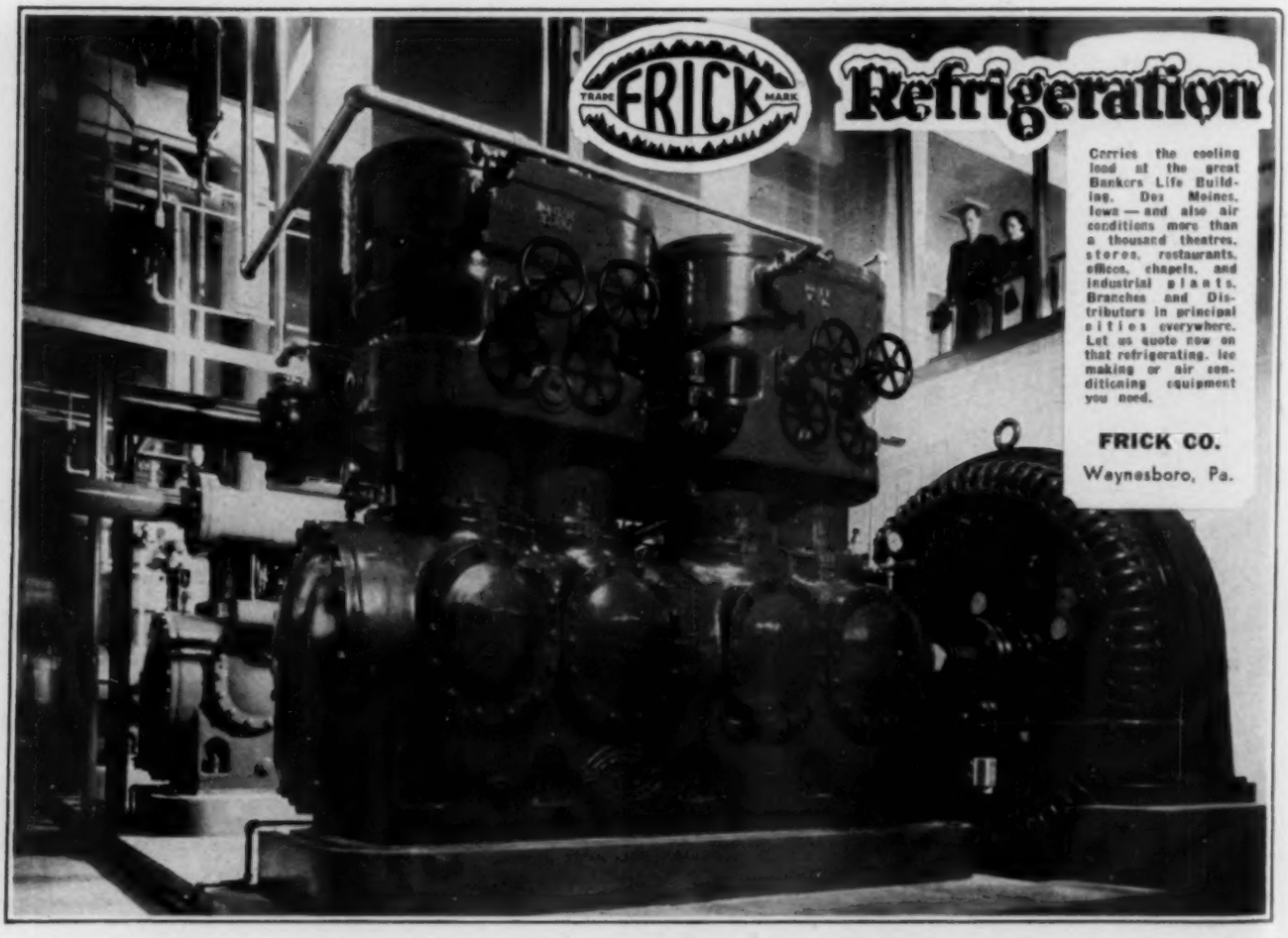
By its installation and adjustment each radiator can be set with the same temperature drop, the maker states. It is claimed that the fitting compensates for variation in resistances through radiators and that each radiator can be adjusted for the correct water flow.

The straight type fitting is applicable for installation in balancing existing as well as new installations. It is installed in connection with a reducing tee leading to each radiator for single pipe jobs and can also be used on the return connection of radiators for balancing two pipe jobs, either gravity or forced circulation.—Sullivan Valve & Engineering Co., 910 S. Arizona St., Butte, Mont.

Air Damper

No. 1906—A device for balancing forced air systems is known as the "Mayn" air damper and is designed to be installed in the register and grille stack heads. It comes complete with the damper blade, hinges, adjusting screws, nut, screw bracket and special adjusting tool.

Features of the product are—the maker states—its automatic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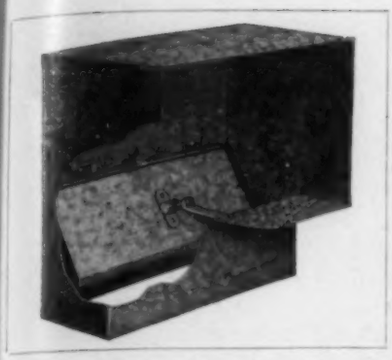
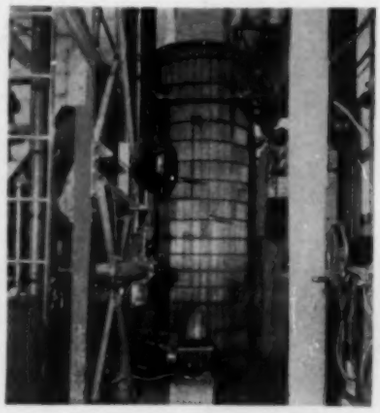
Refrigeration
Carries the cooling load at the great Bankers Life Building, Des Moines, Iowa — and also air conditions more than a thousand theatres, stores, restaurants, offices, chapels, and industrial plants. Branches and Distributers in principal cities everywhere. Let us quote now on that refrigerating, ice making or air conditioning equipment you need.
FRICK CO.
Waynesboro, Pa.



locking device, accessibility with the register or grille in place, positive control of air delivery, and the fact that it is tamper-proof. Rigid construction is employed to eliminate vibration and rattling.—Controlair, Inc., Elyria, Ohio.

Decarbonator for Feedwater Degasification

No. 1907—A decarbonator has been developed primarily to meet the demands of industrial and utility plants for trouble-free boiler feedwater, the maker states. While degasification usually is accomplished during the heating of the feedwater, it may be desirable to remove such corrosive gases as carbon dioxide and hydrogen sulphide from the water in a cold condition without regard to other soluble gases such as oxygen.

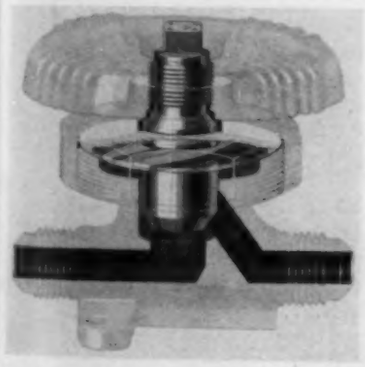


The decarbonator is used to remove carbon dioxide from the effluent of carbonaceous hydrogen zeolite softeners and from water supplies treated with acid. Where soluble iron and carbon dioxide are present in the natural water supply, the decarbonator removes the dissolved carbon dioxide and by aeration oxidizes the soluble iron so that it may be filtered out and the water made fit for use, it is stated.

The decarbonator, constructed mainly of cypress or redwood, is equipped with a rotary blower and fitted with corrosion resistant metals.—Cochrane Corp., 3161 N. 17th St., Philadelphia, Pa.

Packless Refrigeration Valve

No. 1908*—Simplicity is the feature of a new packless valve for the refrigeration field, its maker announces. Embodying modern metals and advanced engineering design, it is claimed that this valve makes for easy installation and trouble free operation.



Features include low over-all height, requiring less installation space; full capacity openings for complete flow of refrigerant; and a beryllium copper diaphragm for fracture and leakproof construction. The handwheel has a natural, oval grip.—Weatherhead Co., 300 E. 131st St., Cleveland, Ohio.

Midget Relay

No. 1909—A new midget relay, known as "Bulletin 105," is designed for use on either a-c or d-c, and is available with contacts arranged for single pole, normally open, normally closed

IT'S A *Smart Move*
TO INSULATE DUCTS WITH
DUX-SULATION

Saves 75% of the Heat Loss. K .27 B.T.U.

High Sound Absorption. 70% in less than 10 lineal feet.

Balances job. Saves Fuel. Quiets Noises.

Fire-Safe with Asbestos Protection built in.

Made especially for Air Conditioning, Ventilating and Warm Air Industries.

Prevents Condensation, Duct Sweating, and Duct Rust.

Inexpensive to use. No material waste. Built to last and stand hard usage.

Moisture proof Surface. Mildew proof Treated. No rotting or chipping.

Convenient to handle in stock or on job. Roll contains 100 square feet.

Standard 1/2" thickness is right thickness for most jobs.

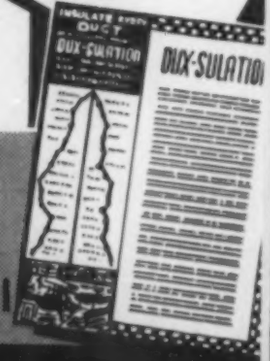
Easiest insulation to apply and looks best.

Low frictional resistance. Smooth surface.

Can be applied on inside or outside of round or rectangular ducts.

Comes Complete, ready to apply. No extras to buy.

Free BULLETIN No. 403



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AIR CONDITIONING

● Kathabar solves difficult control problems in air conditioning by a new and radically different operating principle rather than by devices Humidity and temperature are under simple, separate, independent controls.

Get the facts about Kathabar and see for yourself how easily, accurately and economically you can control humidity and temperature regardless of outside factors.

No matter how you create desired temperature, Kathabar humidity control units can easily be admitted into the specifications. Let us tell you more about it.

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WHAT IS KATHABAR?

Kathabar applies the unique qualities of a chemical called Kathene, the vapor pressure or humidity of which easily can be changed at will. Air coming in contact with Kathene automatically tends to the vapor pressure of the Kathene, thus creating in treated air any desired humidity with absolute precision regardless of weather. Kathene also cleans and deodorizes the air. Kathene is non-inflammable, non-explosive, odorless and inherently harmless. The Kathabar unit is compact, readily accommodated in practically any space and controlled by the simple action of a single valve.

● FOR COMFORT—in hotels, restaurants, public buildings, office buildings, factories, stores, theatres and recreation places.

● FOR HEALTHFUL COMFORT—in hospitals and institutions.

● FOR CONTROLLED DRYING—in factories where materials and their by-products must be dried under controlled conditions.

● FOR SPECIAL ATMOSPHERES—in industries where air conditions affect materials, processes and products.

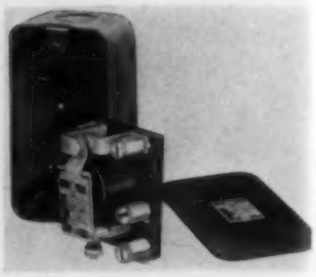
● FOR DRY BLAST—in cupola and blast furnaces where conditioned air is required in combustion.

FOR 34 YEARS THE LARGEST MANUFACTURERS OF GAS-FIRED EQUIPMENT EXCLUSIVELY

SURFACE COMBUSTION

ALSO MANUFACTURERS OF SC INDUSTRIAL FURNACES AND JANITROL GAS-FIRED DOMESTIC AND COMMERCIAL HEATING EQUIPMENT

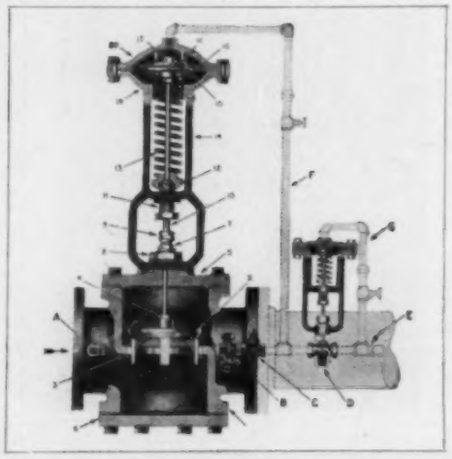
or double throw. It is rated to handle approximately 1 hp and is furnished with coils for operation on standard voltages up to 110/115 volts at standard frequencies. On 220/230 volts, coils can be supplied for not less than 50 cycles.



With over-all bakelite base dimensions of 2⅝ in. by 1⅞ in. and a depth of 1½ in. the relay can be mounted in the wall type pushbutton box.—Ward Leonard Electric Co., 37 South St., Mt. Vernon, N. Y.

Pressure Reducing Regulator

No. 1910—An improved pressure reducing regulator is an auxiliary operated sensitive valve of single seated construction which is adapted for dead-end service, says the maker. For control of steam pressures in the field of public works, housing projects, etc., it is frequently used as a primary control valve, a secondary valve of the weighted lever type being used in conjunction with it.



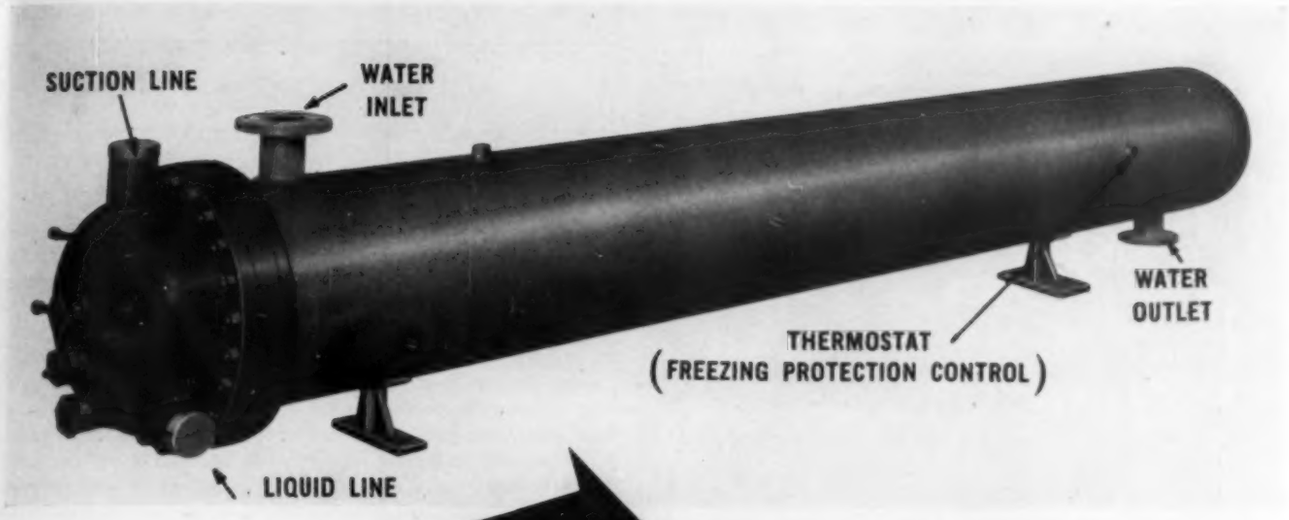
The main valve of this regulator comes in either direct seated (spring opened) or reverse seated (spring closed) as desired.—McAlear Mfg. Co., 1901-1909 S. Western Ave., Chicago, Ill.

Solenoid Valve

No. 1911—A new valve for air at pressures to 75 lb is designed for pilot control of single acting gravity or spring return cylinders or diaphragms which are used for operating valves, dampers, louvers and other mechanical devices. It is particularly well adapted for air conditioning and heating control, according to the maker, as it is tight seating and free from a-c hum.

The solenoid and a simple operating mechanism is arranged so that energization of the solenoid through a three wire control circuit acts to close the port which is open and at the same time opens the port which is closed. This applies pressure to the diaphragm or cylinder, or exhausts pressure from it, according to which of the control lines is closed by the control instrument or switch. The coil circuit is opened, after momentary energization of the solenoid, by contacts mounted with and operated by the solenoid. The valve is mechanically held in either position without continued application of current. The control station makes, but never breaks, the operating current, permitting use of delicate control contacts, says the maker.—Automatic Switch Co., 41 E. 11th St., New York, N. Y.

For your convenience in obtaining more information about any of this equipment, see coupon on page 126. Add the new products and companies listed here to your Directory Section which you received in your January, 1940, HEATING, PIPING AND AIR CONDITIONING and thus keep your records of sources of supply up to date throughout the year . . . Single asterisk (*) indicates equipment not listed in Directory Section; double asterisk (**) equipment and manufacturer not listed



WATER CHILLERS for Air Conditioning Service

The use of water chillers in the comfort cooling of air is increasing because direct expansion of the refrigerant within surface in the air stream is prohibited in many cases and unwise under almost every condition. Whitlock Standard Water Chillers are designed and built by an organization which has specialized in Heat Exchanger work for many years. For engineering assistance, or detailed information, write—

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The Whitlock Manufacturing Co.
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Fisher, Fisher & Hubbell, Denver Archts. N. G. Petry, Gen. Cont. Van Schaak & Co., Agents Univ. Pk. Plbg. & Htg. Co., Htg. Cont.

YOUNG STREAMAIRE CONVECTORS TO HEAT NEW HOUSING DEVELOPMENT

Denver's beautiful new Country Club Garden Apartments, a $1,200,000 project, is the first major FHA housing development in the Rocky Mountain states and consists of five buildings containing 187 individual apartments ranging in size from two to five rooms.

Five heating plants employing forced hot water systems are being installed and 949 YOUNG Streamaire convectors will heat all rooms. The selection of STREAMAIRE convectors for this important group project is a distinct tribute to YOUNG engineering and standards of quality.

YOUNG RADIATOR COMPANY

Racine, Wisconsin

Young Quality

Reg. U. S. Pat. Off.

Sunny San Antonio boasts, among other advantages, one of the most modern, up-to-the-minute Refrigeration Parts Jobbers in the Industry . . . Westbrook's!

Display Shelves are filled with a complete selection of DEPENDABLE A-P Valves. Both Westbrook and their many customers have long ago proved the wisdom of *standardizing on A-P Valves for efficient and accurate Refrigerant Control* on Air Conditioning and Refrigeration Installations.

DEPENDABLE REFRIGERATION Controlled

Protect YOUR Installations—with A-P Valves

A-P offers DEPENDABILITY in a full line of Thermostatic Expansion Valves, Solenoids, Water Valves, Suction Pressure Valves, Oil Valves, Temperature Control Sets, and the new "TRAP-IT" System-Protectors.

New A-P TRAP-IT System - Protector against all Impurities.

A-P No. 215 Thermostatic Expansion Valve. Capacity 3 to 6 tons Freon.

Progressive Service Men Use and Recommend — and Aggressive Jobbers Stock and Talk—A-P Products.

AUTOMATIC PRODUCTS COMPANY
2460 NORTH THIRTY — SECOND STREET
MILWAUKEE WISCONSIN

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Book Reviews

ASTM Proceedings

[Proceedings of the 42nd Annual Meeting. Vol. 39. 1344 + viii pp., 6 x 9 in. Published by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. Prices: paper binding, $8.50; cloth, $9; half-leather, $10.]

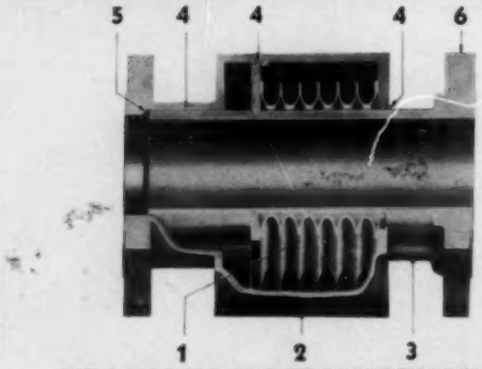
The Proceedings of the 1939 annual meeting of the ASTM are issued in one volume under the society's new publication scheme, by which all new tentative standards (formerly published in the Proceedings) are included in the 1939 Book of Standards, thus enabling the former two volumes—Part I, Committee Reports, and Part II, Technical Papers—to be combined.

Not only do the reports of ASTM committees give full details of the important recommendations on specifications and standardized test methods for materials, but in many cases they include important data and information in the form of appended section reports or papers.

Preceded by the fourteenth Edgar Marburg lecture on Stress, Strain and Structural Damage by Prof. H. F. Moore are 20 papers dealing with metals, 16 covering cement and concrete and masonry materials, eight comprising the symposium on shear testing of soils and 15 covering miscellaneous materials and subjects. Among the latter are five items on industrial waters—particularly boiler feedwater.

Topics covered in the papers on metals include work brittleness test, testing block for heat resisting alloys, mechanical properties of cast iron, contributions on radiography, and mechanical tests on aluminum alloys. In the cement and masonry group are papers covering particle size distribution, a contribution on lean concrete mixes, and several papers on other problems.

ADSCO U-RING JOINT
With PACKLESS FLEXIBLE STEEL ELEMENT



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The only packless expansion joint where the expansion element is under compression when in operation and under minimum flexing strain when in service.

As illustrated above (1) is Expansion Element of corrosion resistant steel welded U-Rings forming a permanent seal between stationary body and movable sleeve (2) Steel Body (3) Movable Sleeve with full, unrestricted opening through joint (4) Three-point guiding for the sleeve throughout entire traverse (5) Limit Stop (6) Flanged ends for pressures to 300 lbs. or with beveled ends for welding. Available with or without anchor base.

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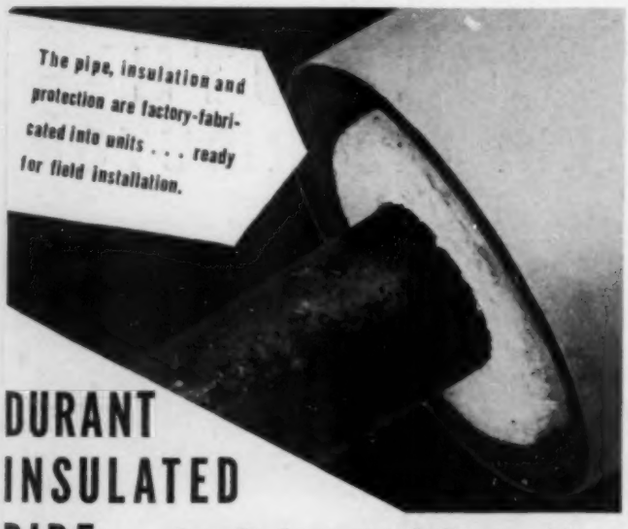
Booklets, Reports and Papers

Discussion on Radiant Heating

More than a dozen in the audience of about 300 took part in the active discussion which followed presentation of my paper on radiant heating at the third annual anthracite conference at Lehigh University. A summary of the items propounded brought forth the pressing need of more research on specific radiant problems, particularly in regard to human reactions. In this connection it was noted that much research had been done in many laboratories, but the data found are either not published or if published are in so many diverse publications that the task of assembling and correlating is rather herculean.

One speaker mentioned a series of experiments made by his company using electrically heated panels or surface in which it was indicated that ceiling heating surface had a deleterious effect on the occupants from a health viewpoint, which was not true for wall heating. It was pointed out that broad generalizations from this alone might lead to improper conclusions as the panel surface temperature, the height of the room and the disposition of other heating surface all entered the picture in addition to ceiling location. There are, of course, many satisfactory installations with at least part of their heating surface in the ceiling.

The question of situating coils in the outside wall and running the possibility of greatly increased heat loss to outside was raised. This may be true, but the installation of a small amount of good insulation behind the coil section minimizes the added loss and the problem is not a serious one. It is a fact that a broad expanse of cold outside wall may be objectionable from a viewpoint of human comfort, and it is sometimes desirable to put heating surface in such a wall to obviate that difficulty.



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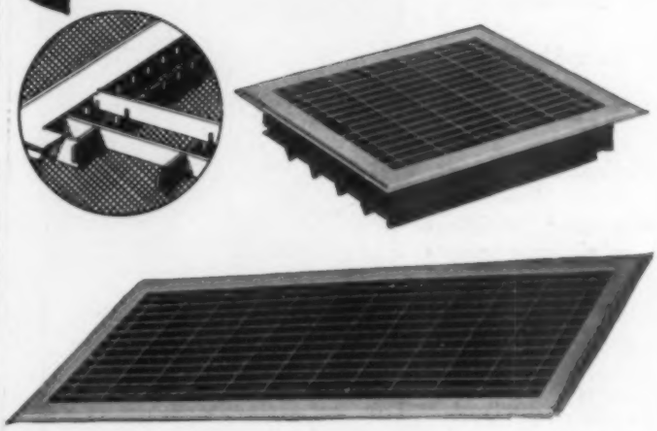

- Multi-lock assembly for surplus strength and extra rigidity.
- All-steel flat bars—mortised at joints, close fitted, perfectly aligned and level.
- Face securely interlocked to frame by tenons at every connection.
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Direct-Fired Unit Heaters for Oil, Gas or Coal ***(hand or stoker fired)***

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- Foundries and Mills
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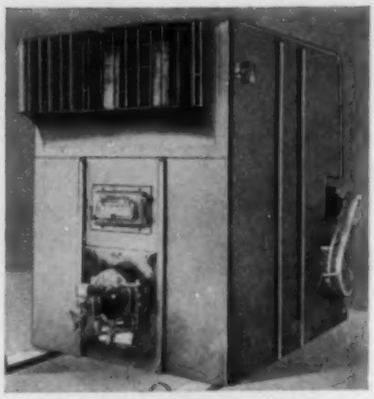


Oil-Fired Directherm Unit Heater

Directherm Unit Heaters are "one-package" heating plants ranging in capacity from 300,000 to 1,500,000 BTU's. These units wherein the heat of combustion is immediately transferred to heating purposes are high in efficiency, low in installation and maintenance cost and their use is flexible because of their ready portability and ease of hooking up.

The Directherm Unit Heater is equipped with a multi-blade centrifugal fan which distributes the warm air throughout the area to be heated, eliminating additional cost for duct work to provide uniform heating. A horizontal high velocity air stream is adjustable to a wide angle of delivery. A duct system can be used to supply a series of separated areas as in a central heating system. The fan is fully capable of overcoming the resistance created in distributing through duct work.

SIX STANDARD SIZES
300,000 to 1,500,000 Btu's.

Directherm direct-fired Unit Heaters are available in six standard sizes, capacities ranging from 300,000 to 1,500,000 Btu's. The Units are made of heavy steel plate, with major sections all-welded. Flue gas headers are readily cleanable.

VENTILATION AND AIR RECIRCULATION. The Directherm can be easily hooked up for outside air intake. Air filters may be used in the intake box when desired.

INSTALLATION. These units, when assembled, require nothing more than a stack and an electrical connection (plus a gas or oil fuel hook-up) and can be made fully automatic in operation when using oil, gas or stoker.

WRITE FOR BULLETIN AND TECHNICAL DETAILS
T•O•D•A•Y•!

Complete literature, ratings and suggested installations on the Directherm direct-fired Unit Heater are available on request. Our Engineering Department will be pleased to give you specific data relative to your particular installation. Send a complete description or blue prints. Write Airtherm Mfg. Company, 718 S. Spring Ave., St. Louis, Mo.

FACTORY REPRESENTATIVES. A few territories still open. Write for details.

AIRTHERM
MANUFACTURING COMPANY
712 S. Spring Ave. St. Louis, Mo.

With radiant heating the air motion, so usual with convection heating, is very much reduced. The question arises whether this motion, considered an essential item in comfort with convective heating, is really so important with radiant heating. Conclusive answers are not available, but it is obvious that some air motion exists even with radiant heating and there are very many radiant heating installations apparently offering no difficulty on this score. However, the problem of air motion with radiant cooling is less definite. Here, with high air temperatures and cool walls, some perspiration must occur and convective air alone removes the ambient air layer around the body.

The discussion brought out the already known fact that radiant heating and cooling is an item of great popular interest and a subject which is being looked into by many and varied commercial interests. Much private and public research is being undertaken. The author himself has for a number of years been collecting and correlating data and is planning further university research work.—B. H. JENNINGS*

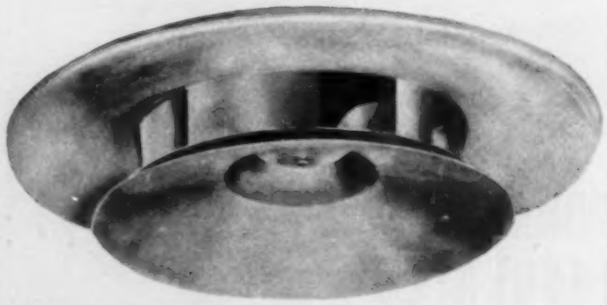
*Department of Mechanical Engineering, Lehigh University.

Air Infiltration Through Windows

Report BMS45 of the Building Materials and Structures series of the National Bureau of Standards is entitled Air Infiltration Through Windows, and was prepared by Eugene F. Coleman and Roy H. Heald. Copies of the 24 p., 8 x 10½ in., paper covered booklet can be obtained from the Superintendent of Documents, Washington, D. C., for 10c.

Equipment for measuring the rate of infiltration of air through the clearance openings of windows and doors due to wind pressure has been developed at the National Bureau of Standards as part of the program of research on building materials and structures. By means of the equipment, tests were conducted on double hung wood windows and light steel casements, types fre-

DEMUTH
AIR DISTRIBUTOR



ACCOMPLISHES three actions necessary to balanced air distribution based on the following patented principles:

1. A circulatory motion which evenly distributes air throughout the room.
2. A Vortex, forming directly below the device, draws the air of the room to the distributor.
3. An Injector principle, providing a recirculation of the room air with the conditioned air, within the device.

PLUS
Unsurpassed beauty which may be combined with standard or special lighting designs. Exclusive installation simplicity. Demuth distributor takes but a few minutes to install.

CHARLES DEMUTH & SONS
JAMAICA, N. Y.

quently specified for low cost housing construction. Infiltration measurements were made for systematic sets of clearance conditions, and correlations between amount of clearance and infiltration are given. The results are summarized using a concise method for representing the relationship between air infiltration and test pressure. Relationships between average sash clearance and infiltration at the reference pressure of 0.2 in. of water are given, and a general type of relation between infiltration and pressure is suggested on the basis of the test results.

A bibliography of 25 selected references on the subject is included.

Research Develops Air Conditioning

Air conditioning was created by research—research seeking to solve certain difficulties in the manufacture of cotton textiles—William B. Henderson, executive vice-president of the Air Conditioning Manufacturers Association, told members of the Heating, Piping and Air Conditioning Contractors National Association at a meeting at the New York World's Fair on May 29. Production problems of the printing industry were basically similar to those of the textile industry; again air conditioning was tried and scored a victory. More and more industries whose processes are affected by air characteristics turned to air conditioning for help, until today over 300, embracing a vast number of different products, find air conditioning almost as indispensable as power or water supply, he said.

As one looks back, it seems almost unbelievable that industrial air conditioning had been in general use for 25 years before any serious attempt was made to adapt it to provide human comfort, Mr. Henderson said. Theaters, harassed by empty houses and dwindling revenues during summer months, turned to air conditioning to save the day. Railroads, restaurants, hotels, stores, office buildings and a host of other enterprises followed the lead of the theaters. It is hard to imagine that all this happened in

Section of Careyduct *Application in Air-Conditioning System of new Kroger Food Foundation Laboratories*

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Hank sez—

$9,000 a Year Was Saved in Fuel

By Shifting This School From Warm Air To Radiator Heating

NOW and agin, you bump inter a feller who looks down his nose at cast iron radiators fur heatin a school.

All yer can do about it, is feel sort o' sorry fur him puttin his nose to a use fur which it warn't built. However, if he wuz handy by right now, I'd tell him something what would make him eat crow. Here's what it would be. And it's a matter of record and being in print besides. So, I ain't done no knocking—repeatin the facts.

The warm air folks did a power o' boastin about the Central School in Wausau, Wisc., being the largest one in the hull U.S.A. heated by warm air. It had 14 furnaces equipped with blowers.

A regiment of firemen shoveled $12,000 worth of coal into 'em every winter, and still school had ter often be let out so they could go home ter warm up. Finally the board got up on its hind legs and had the furnaces tore out and replaced by boilers. 3 carloads of radiators wuz installed.

The coal bill is now $3,000. A plumb $9,000 a year saved. And so fur nobody has ever went home ter keep their feet from gettin chill blains.

These is just a few of the facts about radiator heating, as agin warm air. If you want 'em all, I'll be glad to send you the hull of 'em as published in an article by the Plumbing & Heating Industries Bureau in the June issue of the Nation's Schools.

HANK HINDLE.

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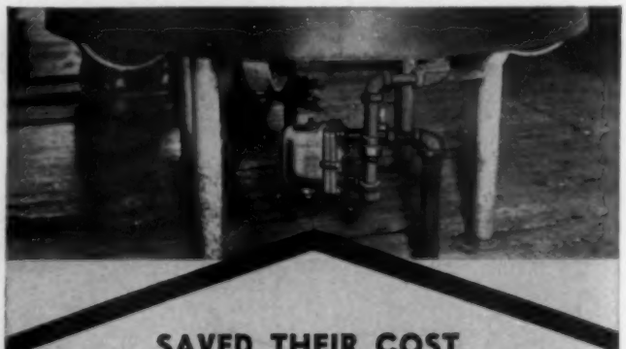
the short space of 15 years, particularly when one remembers that the period of greatest growth in the use of air conditioning for human comfort and business profits was the period of the greatest economic depression the world had ever known. Few realize, even those of us who live close to the air conditioning industry, what an integral and almost indispensable part of our scheme of things air conditioning has become. In the making of the clothes we wear, in the preparation of the food we eat, in the production of the equipment we use every day—whether it be an automobile, a camera or a knife and fork—air conditioning makes its contribution.

Fortunately, air conditioning did not become the mushrooming industry which was to "lead us out of the depression," as so many thoughtless people prophesied in the dark days of 1932 and 1933, Mr. Henderson said in conclusion. Rather, it has infiltrated steadily and irresistibly into every nook and cranny of our daily life.

Simplified Practice Recommendation for Cast Iron Radiators

Printed copies of Simplified Practice Recommendation R174-40, Large Tube, Cast Iron Radiators, are now available, according to an announcement of the division of simplified practice, National Bureau of Standards. The recommendation gives the number of tubes, catalog rating per section and dimensions of 17 sizes of radiators and is the result of a study of demand for various sizes made by the Institute of Boiler and Radiator Manufacturers. This simplified list of 17 sizes, according to the institute, will meet all requirements for which 33 sizes had been produced, and will serve the best interests of all concerned.

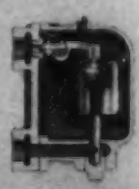
Copies of this recommendation, which was approved for promulgation on March 1, 1940, may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5c each.



SAVED THEIR COST
10 times the first year

Jaffe Barton Tire Company, of New York, had trouble warming up the plant on cold mornings. The Sarco man said, "The trouble is not so much with your heating system as it is with the steam hook-up on your vulcanizers. You should have individual steam traps on each machine."

RESULT—Sarco Bucket Traps on each machine reduced vulcanizing time from 60 to 50 minutes, saving half a cent a tire, or $2,000 a year. A Sarco Float-Thermostatic Trap on the unit heater in the drying room increased production, helped reduce vulcanizing time. A minor change in the heating system did the rest.



And now the plant starts off on the coldest mornings at top speed. The Sarco Representative in your vicinity knows both heating and industry. Why not call him or write for Catalog No. 165.

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American Society of Mechanical Engineers: Fall meeting, September 3-6, Hotel Davenport, Spokane, Wash. Headquarters office, 29 W. 39th St., New York, N. Y.

Eastern States Exposition: September 15-21, Springfield, Mass. For further information address J. H. Fifield, Eastern States Exposition, Springfield, Mass.

National Industrial Advertisers Association: Annual Conference and Exposition, September 18-20, Hotel Statler, Detroit, Mich. President, Charles McDonough, Combustion Engineering Co., Inc., 200 Madison Ave., New York, N. Y.

American Society of Heating and Ventilating Engineers: Fall meeting, October 14-17, Rice Hotel, Houston, Tex. A. V. Hutchinson, secretary, 51 Madison Ave., New York, N. Y.

Power Show: 14th National Exposition of Power and Mechanical Engineering, December 2-7, Grand Central Palace, New York, N. Y. Under management of International Exposition Co., Grand Central Palace, New York, N. Y.

American Chemical Exposition: December 11-15, Stevens Hotel, Chicago, Ill. Under auspices of Chicago section, American Chemical Society. Exposition manager, Marcus W. Hinson, 110 N. Franklin St., Chicago, Ill.

Refrigeration and Air Conditioning Exhibition: January 13-16, Stevens Hotel, Chicago, Ill. Sponsored by Refrigeration Equipment Manufacturers Association, R. M. McClure, Executive Secretary, 111 W. Washington St., Chicago, Ill.

American Society of Heating and Ventilating Engineers: Annual meeting, January 27-29, Hotel Muehlebach, Kansas City, Mo. A. V. Hutchinson, secretary, 51 Madison Ave., New York, N. Y.

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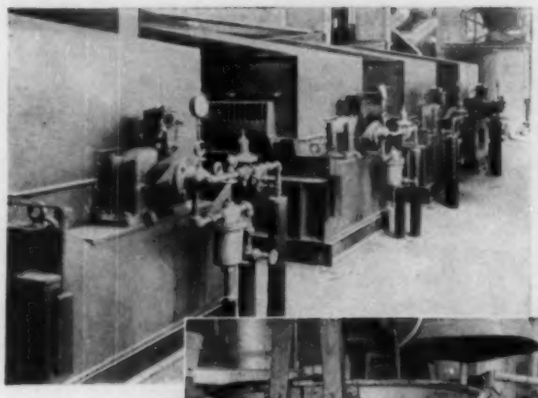

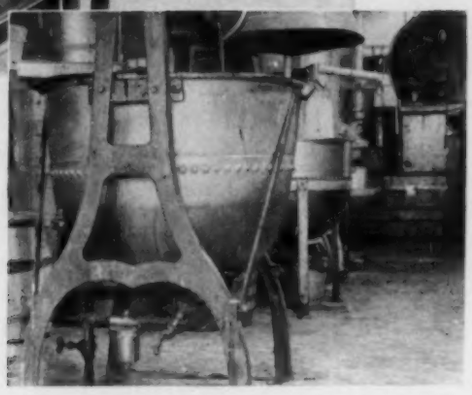

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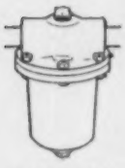

—straight-in-line using the optional inlet. In either case, no extra fittings to buy or install.

Showing Thermal element in both positions. Always either wide open (A), or tight shut (B), never partly open or almost closed.

Snap action heat saves time on batch processing, giving more batches per day. You get snap action heat—instant heat—from Anderson Super-Silvertops equipped with snap action air eliminators.

These time-saving eliminators are wide open when steam is first turned on. The pressure blasts the air out of the unit which then becomes filled with hot, dry steam. When steam reaches the trap, the snap action element reverses itself (see sketch below, left) closing the auxiliary air ports and preventing any steam loss.

Typical time savings reported with snap action heat are: 23 minutes on dry room coils and 25% of cooking time on a 48" starch cooker. You, too, can make real savings in time on process heating—by using snap action eliminators to get snap action heat. Write today for the folder "Snap Action Heat." It shows why snap action heat saves time and steam. Write today for your copy.

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Super-Silvertop STEAM TRAPS

Recent Trade Literature

For your convenience in obtaining copies of these bulletins, see coupon on page 126. If you write direct to the manufacturer, describe carefully what literature you want, as the number given first in each item is for use only when sending your request to HEATING, PIPING AND AIR CONDITIONING.

No. 3565. AIR CONDITIONERS: Carrier Corp., 302 S. Geddes St., Syracuse, N. Y. Three specification sheets describing air conditioning units for use in multiroom buildings. The duct type "Weathermaster" comes in six sizes for office buildings and large residences. Cooling and heating of apartments, hospitals, hotels and office buildings is provided by the "Thermomaster" without the use of ducts, and another ductless unit, the ventilating "Thermomaster," is designed for cooling, heating, filtering and ventilating individual rooms in apartments, hospitals, hotels and offices.

No. 3566. AIR CONDITIONERS: Carrier Corp., 302 S. Geddes St., Syracuse, N. Y. Three specification sheets on "Weathermaker" air conditioning units for use in stores, restaurants, offices and commercial buildings.

No. 3567. AIR CONDITIONERS: Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill. 20 p. booklet (ACB110.4) discussing methods of air conditioning, and illustrating and describing in detail the manufacturer's line of self-contained, central station, and remote type units and their construction. Information on various applications and testimonials showing how air conditioning pays are included.

No. 3568. AIR CONDITIONERS: Frick Co., Waynesboro, Pa. 20 p. booklet trimmed in the shape of an air conditioning unit, discussing advantages of unit air conditioners, their installation, features of the maker's units, method of operation and control.

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FOR HEATING AND COOLING

AVAILABLE IN A WIDE RANGE OF SIZES

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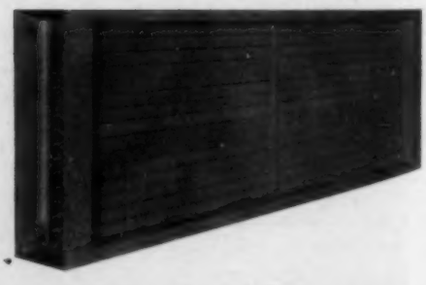

WATER COOLING COILS

THE G&O MANUFACTURING COMPANY
New Haven, Connecticut
Pioneer Manufacturers of Square Finned Tubing in the United States

No. 3569. AIR CONDITIONERS: General Electric Co., Air Conditioning and Commercial Refrigeration Dept., 5 Lawrence St., Bloomfield, N. J. 12 p. booklet on room air conditioners as a "new and better method of personal weather control," describing three types of unit systems, their advantages, and presenting features and specifications of and performance data on the manufacturer's units.

No. 3570. AIR CONDITIONERS: Westinghouse Electric & Mfg. Co., East Springfield, Mass. Leaflet (9HC-0626) describing three new gas fired air conditioning units for builders and owners of apartments and small homes.

No. 3571. BEARINGS: Johnson Bronze Co., 460 S. Mill St., New Castle, Pa. The first three of a series of data sheets on "Ledaloyl," a self-lubricating sintered bearing. The sheets give data on method of installation, operating temperature, and chemical and physical characteristics.

No. 3572. BOILERS: Kewanee Boiler Corp., Kewanee, Ill. 8 p. catalog (89) on "Hi-Test" welded, two pass, portable boilers with refractory lined fire boxes for power and industry process steam. Available in six sizes from 50 to 150 hp and for 125 and 150 lb pressure..

No. 3573. BOWLING ALLEY AIR CONDITIONING: Carrier Corp., 302 S. Geddes St., Syracuse, N. Y. 4 p. bulletin on Bowling—a Year 'Round Sport—telling how bowling activities do not have summer slumps in air conditioned recreation halls, and giving actual experiences.

No. 3574. CONDENSING UNITS: Carrier Corp., 302 S. Geddes St., Syracuse, N. Y. Four 2 p. bulletins (CR-138, CR-139, CR-140, CR-148) on new V type refrigeration condensing units, both air and water cooled, the former being available in 2 and 3 hp sizes, and the latter in 2, 3, 5 and 7½ hp.

No. 3575. CONDENSING UNITS: General Electric Co., Air Conditioning and Commercial Refrigeration Dept., 5 Lawrence St., Bloomfield, N. J. 60 p. catalog on condensing units for air conditioning and refrigeration, available in a full range of sizes from 5 to 60 hp. Information on design and features, di-

REDUCE THE HUMAN ELEMENT

TH' ROOSTER THINKS IT'S SUNRISE, POODY 'CAUSE "NUTTY" GOT TIRED A'FORE FANNIN' OUT THE LIGHT!

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If air conditioning units were made to be pampered — but why suppose? They're not. The demand is for a unit that will blow hot or cold 24 hours a day and never stop 'til the cows come home. Any good unit can answer this demand if it operates on a super-powered shaded-pole induction type Victor Motor. A motor that lends itself to complete speed control. A motor whose oversized oil-impregnated self-aligning bearings portion out oil in just right quantities — never too much — never too little. There is a rugged dependable Victor Motor for any device within the range of 1/200 to 1/10 H.P. The Victor engineers love to tackle tough motor problems. Let's get started on yours. Write today and tell us your troubles.

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Air conditioners (Winter or summer) - Evaporative coolers - Auxiliary blowers and fans - Cabinet Heater Circulators - Cold air return boosters - Warm air pipe boosters - Window ventilators - Auxiliary draft blowers for oil burners, gas burners, and stokers.

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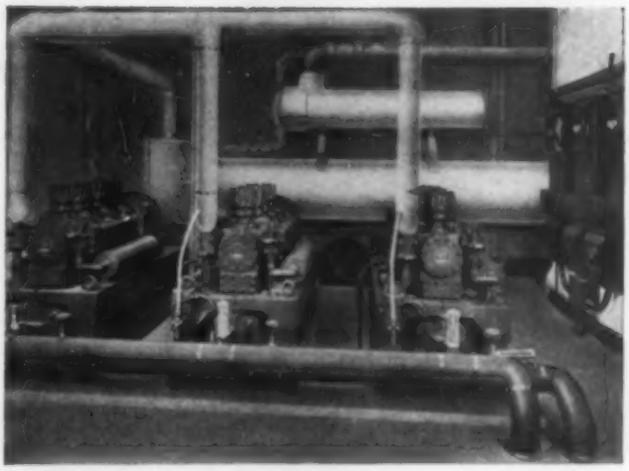

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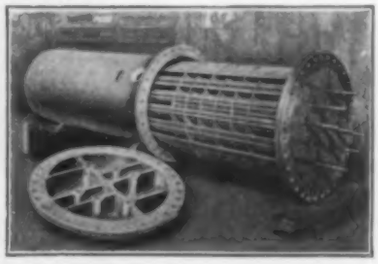

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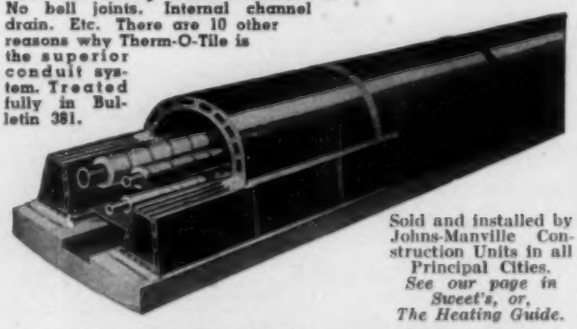

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mension and outline drawings, performance, accessories, mounting, and on pressure drop in refrigerant lines is included.

No. 3576. CONTROLS: Automatic Control Co., 2590 University Ave., St. Paul, Minn. Catalog (C-3) on automatic controls for water, sewage and industrial use, made up of individual bulletins on the various items of equipment for this service.

No. 3577. COOLING SURFACE: General Electric Co., Air Conditioning and Commercial Refrigeration Dept., 5 Lawrence St., Bloomfield, N. J. 38 p. technical bulletin on direct expansion cooling surface—featuring the "electro thermal bond"—describing construction and the "selected performance method" with performance tables for various conditions. The laws of surface cooling are discussed in some detail and the "exact selection method" is described and its use explained. Information on thermostatic expansion valves for use with the coils, piping diagrams and connection sizes, and pressure drop tables, are included, as is a psychrometric chart and a table of total heat of air at various wet bulb temperatures to tenths of a degree.

No. 3578. DEHUMIDIFIERS: Aqua-Sorb Co., 21 S. 16th St., East Orange, N. J. 4 p. bulletin describing "Aqua-Sorber" dehumidifying unit of small size for eliminating dampness and high humidity. The units use a hygroscopic absorptive material which slowly dissolves and is replaced.

No. 3579. DUST COLLECTORS: American Foundry Equipment Co., 619 S. Byrkit St., Mishawaka, Ind. 1 p. circular (32) on a new cyclone dust collector, illustrating and describing its features. Also a 12 p. catalog (60) on the manufacturer's line of abrasive blasting equipment, including data on "Dustube" dust collectors and other equipment.

No. 3580. EVAPORATIVE COOLERS: Hall Mfg. Co., Cedar Rapids, Ia. 6 p. folder on "Kumfort Koolers" which draw in 100 per cent outside air, clean the air, cool it evaporatively and circulate it throughout the room. Capacity and dimensional data are included.

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No. 3581. EXPANSION JOINTS: Yarnall-Waring Co., Chestnut Hill, Philadelphia, Pa. 16 p. bulletin (J-E1907) on "Gun-Pakt" cylinder guided expansion joints of all wrought steel construction which may be packed under full steam pressure. Information on figuring expansion in pipe lines and anchors for pipe lines is included as are tables of prices and weights of expansion joints, dimensions and views of typical installations.

No. 3582. FANS: Emerson Electric Mfg. Co., 1847 Washington Ave., St. Louis, Mo. Spirally bound portfolio on the manufacturer's 1940 line of fans, including desk and floor circulating fans, ceiling fans, kitchen ventilating fans, exhaust fans, information on installing exhaust fans with ducts and other data.

No. 3583. FANS: Truflo Fan Co., 523 Main St., Harmony, Pa. 4 p. bulletin on features of man cooling fans available in five different types and including specifications.

No. 3584. GRILLES: Diamond Mfg. Co., 253 W. Eighth St., Wyoming, Pa. 112 p. specification book on grilles and registers for air conditioning, heating and ventilating, divided into two sections. The first is on architectural grilles of heavy perforated metal and the second on air conditioning registers. Complete information and illustrations are presented. Also, a 16 p. catalog (33) on perforated metals and perforated metal products for industrial uses.

No. 3585. HEAT CONTROLS: Burling Instrument Co., 4 Belmont Ave., Newark, N. J. 4 p. bulletin on the manufacturer's heat controls which may be used in liquids or gases and from temperatures as low as minus 100 to as high as plus 1400 F. Information on applications, and specifications of the instruments, are given.

No. 3586. HUMIDIFIERS: Maid-O'-Mist, Inc., 215 N. Aberdeen St., Chicago, Ill. Leaflet (701) illustrating and briefly describing the various types of the manufacturer's humidifiers, and several heating specialties.

No. 3587. INSULATION: Grant Wilson, Inc., 4115 W. Taylor St., Chicago, Ill. 8 p. bulletin (400) on the insulation of ducts with asbestos protected "Dux-Sulation." The necessity

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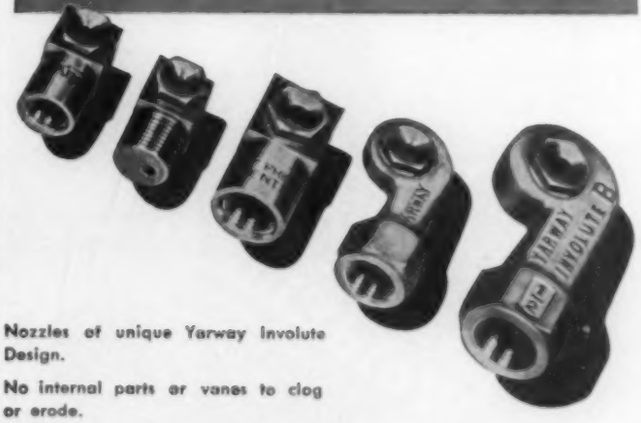

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of applying insulation to ducts for both cool and warm air is discussed as are the subjects of preventing condensation and reducing noise transmission. A table is included showing the outside surface temperature of ducts covered with this insulation.

No. 3588. MECHANICAL RUBBER GOODS: B. F. Goodrich Co., 548 S. Main St., Akron, Ohio. 24 p. condensed catalog of engineering data, for purchasing agents and plant maintenance men, on mechanical rubber goods. Data are included on rubber transmission belting, v-belt drives, hose and fittings, hard rubber sheet and pipe, rubber lined tanks, vibration insulators and other products.

No. 3589. METHYL CHLORIDE: E. I. du Pont de Nemours & Co., Inc., R. & H. Chemicals Dept., Wilmington, Del. 32 p. revised booklet on methyl chloride, conforming with the results of recent research and featuring a three color Mollier chart and new tables of thermodynamic data. Included with the new information on refrigeration service problems are chapters on moisture, lubrication, pressure drop and transfer of refrigerants. This booklet is a complete technical and practical discussion of methyl chloride and is carefully indexed.

No. 3590. MOTORS: Century Electric Co., 1806 Pine St., St. Louis, Mo. 4 p. bulletin (BCA 120.0) on split phase motors for application to oil burners, unit heaters and other duties, describing and illustrating their features.

No. 3591. MOTORS: Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. 2 p. illustrated leaflet (F8537) describing polyphase, squirrel cage induction motors in fractional horsepower sizes for constant speed applications requiring normal or high torque characteristics. Also, a 2 p. leaflet (F8533) on fractional horsepower, constant speed, direct current motors in either shunt or compound wound types.

No. 3592. PIPE COILS: Frick Co., Waynesboro, Pa. 6 p. bulletin (156-B) on engineered pipe coils for refrigeration work, illustrating and describing the types available and their construction, and showing a number of applications.

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No. 3593. PYROMETERS: Leeds & Northrup Co., 4970 Stenton Ave., Philadelphia, Pa. Broadside (N-33) describing briefly the manufacturer's complete line of industrial temperature instruments, showing the choice available, important features of each, and listing the specific publications where more detailed information can be had. Discussion of accessory equipment is included.

No. 3594. REGISTERS: Independent Register Co., 3747 E. 93rd St., Cleveland, Ohio. Leaflet giving sizes and list prices of baseboard registers of the one piece style—grille not removable.

No. 3595. STEAM TRAPS: Yarnall-Waring Co., Chestnut Hill, Philadelphia, Pa. 16 p. bulletin (T-1735) on impulse steam traps, describing and illustrating their features, explaining operating principle, and giving instructions on selection, installation, operation, with tables of capacities and prices, weights and dimensions, etc.

No. 3596. STORAGE WATER HEATERS: Kewanee Boiler Corp., Kewanee, Ill. 12 p. catalog (94) on storage water tank heaters for hot water service with reserve for sudden demands, with storage capacities ranging from 95 to 2240 gal, and heater capacities 50 to 6000 gph.

No. 3597. THERMOMETERS: Bristol Co., Platts Bridge, Waterbury, Conn. Bulletin (524) on industrial glass stem thermometers, manufactured as a supplement to a complete line of recording and controlling thermometers. Information is given on sizes, dimensions, bulbs, ranges, finish and the "easy to read" mercury column.

No. 3598. VALVES: Homestead Valve Mfg. Co., P. O. Box 348, Coraopolis, Pa. 4 p. bulletin on the manufacturer's valves, describing them briefly and showing applications. A table on the cost of steam, water and air leaks through various sizes of openings is included. Also, a leaflet describing the construction and applications of the manufacturer's quick operating shut-off valves for small air, gas or cold water lines.

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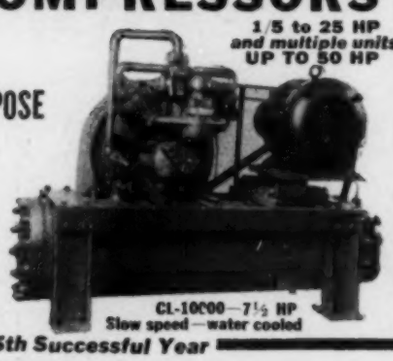

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No. 3599. VIBRATION ISOLATION: Korfund Co., Inc., 48-15 32nd Pl., Long Island City, N. Y. 4 p. bulletin on isolation of machinery vibration and noise with "Vibro-Isolators," giving a discussion of the subject, sketches and photographs, and installation instructions.

No. 3600. WELDING AND SOLDERING EQUIPMENT: Imperial Brass Mfg. Co., 1200 W. Harrison St., Chicago, Ill. 28 p. booklet on a complete line of welding and cutting torches and outfits, soldering outfits, gas and air torches and lead burning equipment. A new torch recommended by the maker for welding sheet metal is shown.

No. 3601. WELDING PRODUCTS: Air Reduction Sales Co., 60 E. 42nd St., New York, N. Y. 32 p. catalog (103) on "Airco" electric welding products, describing a complete line of electrodes and welding machines. A discussion is given on various types of electrodes and suggestions are offered as to where each can be used to best advantage.

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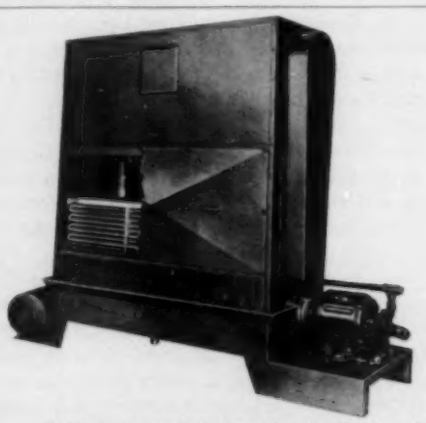

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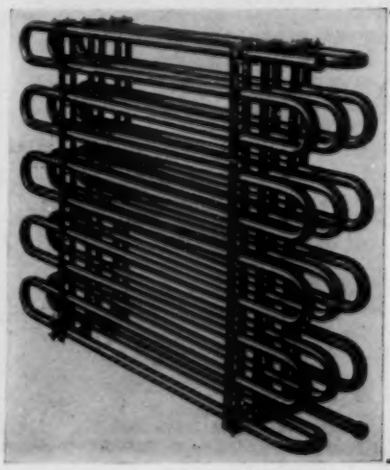

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